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# Effects of Head Position and Head-Supported Mass on Nerve Function of the Flexor Carpi Radialis Muscle in Healthy Individuals

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**EFFECTS OF HEAD POSITION AND HEAD-SUPPORTED MASS ON NERVE  
FUNCTION OF THE FLEXOR CARPI RADIALIS MUSCLE IN HEALTHY  
INDIVIDUALS**

**EFFECTS OF HEAD POSITION AND HEAD-SUPPORTED MASS ON NERVE  
FUNCTION OF THE FLEXOR CARPI RADIALIS MUSCLE IN HEALTHY  
INDIVIDUALS**

A dissertation submitted in partial fulfillment  
of the requirements for the degree of  
Doctor of Philosophy in Kinesiology

By

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## ABSTRACT

Long-term exposure to head-supported mass (HSM) has been linked with spinal degeneration including foraminal stenosis and disc deterioration. Anecdotally, HSM has also been linked to neck and arm pain and muscle atrophy, but nerve function has not been tested specifically. The combined effect of various head positions and HSM may be sufficient to compress the nerve root in aviators and Soldiers during job performance, potentially leading to short- and long-term neuromuscular effects. The Hoffmann (H) reflex, a well-established measure of nerve function, has shown to be sensitive to changes in nerve root space which occurs with different head positions. This study assessed the validity of the H-reflex as an assessment tool of nerve function under varied HSM loading conditions in various head positions. The H-reflex was tested in the flexor carpi radialis muscle of the right arm in a healthy population with no recent history of HSM use. Participants ( $n = 14$ ) were tested under three different HSM conditions: no HSM, a low weight-moment configuration, and a high weight-moment configuration. Following a 25-minute exposure period, each HSM condition was tested in neutral and at the end point of active range of motion for four different head positions: flexion, extension, and left/right rotation. Ten stimuli were averaged for each position and compared to a neutral unloaded baseline. An expected decrease in flexion was greater under the low-weight moment condition than the no HSM ( $d = 0.19$ ), and in the high weight-moment condition than in the low weight-moment condition ( $d = 0.34$ ). Unlike previous studies which found amplitude increases, there is evidence of an amplitude decrease in extension ( $d = 0.49$ ) and right rotation ( $d = 0.32$ ) when comparing the high weight-moment condition to the low weight-moment condition. Similarly, left rotation showed a decrease in amplitude that was greater in

the low weigh-moment condition than the no HSM condition ( $d = 0.48$ ). As expected, there was no effect of HSM or head position on latency. The results indicate that the combination of HSM and head position may contribute to a mechanical compression of the nerve root and decreased function.

This dissertation is approved for recommendation  
to the Graduate Council.

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## **ACKNOWLEDGEMENTS**

I began this journey eight years ago with every intention of graduating quickly and beginning a successful career. I had no way of knowing the missteps, detours, and challenges that awaited me. From Fayetteville to Fort Rucker, Baghdad to Walter Reed, and back, this journey is finally coming to an end and I will be forever grateful to those who have helped me along the way. As I move forward now as “Dr. Shivers”, I am reminded of the many names and titles I’ve been given along the way: “Molly”, “Sis”, “BB”, “LT”, “B” – student, daughter, cousin/niece, aunt, leader, and friend. Whereas this degree will define my career, these relationships define my character and they are the true foundation of my success.

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## **DEDICATION**

To all the brave men and women serving our nation around the world – thank you for your service and sacrifice.

To the Soldiers of the 217<sup>th</sup> MP Company, especially 3<sup>rd</sup> Platoon – it is an honor to serve, it is a privilege to lead, it is a truly humbling thing to have your Soldiers care about you.

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## **CHAPTER ONE**

### **Introduction**

Military helmets provide blunt impact protection and serve as a mounting platform for vital technologies such as night vision goggles and head-up displays. The utility of these helmets and other types of head-supported mass (HSM) is offset by the significant load imparted to the neck of aviators and Soldiers. This load has been associated with spinal degeneration (Froom et al., 1984; Hamalainen et al., 1999; Hamalainen et al., 1996; Landau et al., 2006; Pippig & Kriebel, 2000) and anecdotally linked with increased incidence of acute and chronic neck and arm pain as well as musculoskeletal atrophy. Aviators and Soldiers alike are required to hold their head in static positions throughout their range of motion during normal operational tasks. The potential negative effects of HSM could be significantly compounded if the head is held in a position other than the neutral position which is most stable. Head-supported mass has been researched as it relates to user performance and injury risk during impact, but little research has examined the physiologic impact of HSM, particularly as it relates to statically held head positions (Alem, Meyer, & Albano, 1995; Barazanji & Alem, 2000; Butler & Alem, 1997; and Fraser, Alem, & Chancey, 2006). Despite the implication of nerve involvement, there are no studies relating the effect of HSM on nerve function. The goal of this study was to determine the practicality and validity of the Hoffmann Reflex (H-reflex) as a tool for assessing the combined effect of HSM and head position on nerve function.

Although the issue of neck pain and degeneration is pertinent for all military personnel regardless of job type, it is of particular interest for aviators due to the unique environment in which they operate. Whereas other job types may afford Soldiers opportunity to get up and walk around or even remove their helmets briefly for relief, aviators are confined to the cockpit for



hours at a time and are restricted to minimal body position and helmet adjustments for pain relief. According to a survey of the Total Army Injury and Health Outcomes Database (TAIHOD) (2005), more than 1.2 million neck and back related injuries were documented among Army personnel between 1980 and 2002. These injuries resulted in over one million outpatient visits and 1,218 disability evaluations. The overwhelming majority of outpatient visits were for neck pain with diagnoses ranging from intervertebral disc disorders, spondylosis with myelopathy, and segmental/somatic dysfunction. Aviators were found to have a significantly higher rate of neck and back pain than other job specialties (Amoroso, Bell, Toboni, & Krautheim, 2005). This finding is supported by Aydog et al. (2004) who reported that helicopter pilots had higher incidences of osteoarthritic changes in the cervical region compared to pilots of other aircraft or a non-pilot control group. Other studies also report helicopter pilots experience neck pain including radiating, radicular, and localized symptoms (Bridger, Groom, Jones, Pethybridge, & Pullinger, 2002; Pippig & Kriebel, 2000; Harrison et al., 2011). Reports of neck and back pain increase significantly as flight time increases both on mission and accumulated over time. Back pain can begin as soon as two hours (hrs) into the flight and last from 30 minutes (min) to four hrs following the flight (Thomae, Porteous, Brock, Allen, & Heller, 1998). Reports of neck and back pain increase significantly as flight time increases both on mission and accumulated over time.

Traditionally, research related to HSM has focused on the ability to proficiently perform duty related tasks and injury risk during impact (Fraser, Alem, & Chancey, 2006; Alem, Meyer, & Albano, 1995; Barazanji and Alem, 2000; Butler and Alem, 1997). Research examining the effect of HSM and loading on spinal degeneration most commonly focuses on the high g

environment ranging from 2 to 7 g. Multiple case studies have linked high g exposure to incidences of radiculopathy, myelopathy, weakness, evidence of spinal degeneration, and a decrease in spinal height (Hamalainen *et al.*, 1999; Hamalainen *et al.*, 1996).

The majority of military personnel work either on the ground (on foot or in ground-based vehicles), in rotary aircraft or in small fixed wing aircraft, and are thus operating in a low g environment. While, high g exposure most likely concentrates the effects of HSM on the spine manifesting in musculoskeletal symptoms at a quick rate of onset; chronic exposure to HSM in a lower g environment may produce similar symptoms, but at a much slower rate. A number of studies have documented degenerative changes in high and low g environments. Specifically, cervical and lumbar pathology were more common in fighter (high g) and helicopter (low g) pilots than in transport pilots (low g); and spondylolisthesis more common in helicopter pilots than all other pilot groups (Froom *et al.*, 1984; Pippig and Kriebel 2000, and Landau *et al.*, 2006)

Spinal degeneration related to HSM is not isolated to military populations. Several studies have loads of 20 to 30 kg, like the load porters carry on their heads, are linked to significant spinal degeneration (Jager, Gordon-Harris, Mehring, Goetz, & Mathias, 1997; Joosab, Torode, & Prasada Rao, 1994). Limited research is available on the effects of smaller doses of HSM, such as that of the weight of a helmet with added devices, as a cause of acute pain or long-term degeneration.

Although there is no definitive link between HSM and acute changes in spinal height, there is limited evidence that spinal height changes occur in postures and loading conditions common to aviation. Spinal height changes of up to 19mm are expected diurnally (Tyrrell, Reilly & Troup, 1985). One study demonstrated that after spending an hour with the head held at 20°

and 40° flexion there was a significant decrease in height when compared to the head held in a neutral position (Bonney & Corlett, 2002). As mentioned previously, aviators frequently spend extended periods of time with their heads fixed in awkward positions. For instance, the co-pilot gunner in the AH-64 Apache spends a large portion of a flight looking at a target locator screen which requires holding the head in a forward flexed position. Hamalainen et al. (1996) found that fighter pilots' height decreased by almost five millimeters (mm) after performing aerial combat maneuvers under a mean of + 7.2 g. In this same sample of pilots, significant height change also occurred after sitting for 30 min in an aircraft on the ground while wearing standard protective equipment. While neither Bonney and Corlett (2002) nor Hamalainen et al. (1996) found height changes greater than that which might be expected diurnally, the changes in height occurred in a very short amount of time, an hour or less, versus throughout the course of a day.

Despite the implication and probability of nerve involvement suggested by the nature of the signs and symptoms described and documented thus far (e.g., muscle degeneration, numbness and tingling in the arms and hands, pain), no research has examined changes in nerve function relative to HSM. One method of testing nerve function, commonly used in both clinical and research environments, is the H-reflex. The H-reflex has been shown to be a reliable and valid measure of nerve function which is sensitive to any disturbance or alteration of the nerve pathway (for a review see Palmieri, Ingersoll, & Hoffman, 2004). In the upper-body, the nerve and muscle commonly used for H-reflex testing are the median nerve and flexor carpi radialis muscle (FCR). The median nerve and FCR are ideal for studying the neck because portions of the spinal nerve roots from C5 to T1 merge together to form the median nerve.

The H-reflex has been shown to be sensitive to acute changes in the nerve root space. Sabbahi and Abdulwahab (1999) found that H-reflex amplitude increased when the head was positioned in extension, rotation, and lateral flexion compared to neutral; amplitude decreased in flexion when compared to neutral. The increase and decrease in amplitude were believed to be due to changes in the nerve root space and decompression/compression of the nerve root itself which would alter its ability to transmit the stimulus to the FCR. Abdulwahab and Sabbahi (2000) found that H-reflex amplitude recorded after a series of neck retraction exercises increased compared to H-reflex amplitude recorded after a 20-min period of reading with the head in a partially flexed position. The neck retractions increased the nerve root space compared to the decreased space from the flexed position. Similarly, Hiraoka & Nagata (1998) found that H-reflex amplitude in the FCR increased with cervical traction in individuals with diagnosed radiculopathy. When compared to the prone position, soleus H-reflex amplitude decreased bilaterally with participants standing, standing holding an additional load, and with bodyweight unloaded by 25% (Ali & Sabbahi, 2000). The same group found that the addition of a 4.5kg helmet facilitated the H-reflex amplitude in the flexor carpi radialis muscle with the head in a neutral position when compared to seated without load and lying supine (Al Rowayeh et al., 2010). The researchers believed this was due to increased excitability of the cervical spinal motoneurons as a result of the increased cervical spinal and postural muscle contraction to support the weight of the helmet. The H-reflex was measured immediately following donning the helmet and does not account for any potential short-term changes in disc height and nerve root space resulting from the added mass. The study also tested only in the neutral head position and did not analyze the effect of added mass on mechanical compression of the nerve root which

the same group believed occurred in the flexed position. Hwang et al. (2011) found that H-reflex amplitude in the soleus muscle decreased significantly as body weight was progressively unloaded indicating decreased spinal motorneuron excitability.

Head-supported mass has been linked with acute and chronic pain as well as spinal degeneration (Hamalainen et al., 1999; Hamalainen et al., 1996; Pippig & Kriebel, 2000; Landau et al., 2006; Froom et al., 1984). Although nerve involvement is implied by the symptoms and conditions documented, no research has focused on examining nerve function in an aviation population. There is evidence of acute changes in median nerve function in different head positions presumably due to a mechanical compression of the nerve root (Sabbahi & Abdulwahab, 1999; Abdulwahab & Sabbahi, 2000; Hiraoka & Nagata, 1998). It is unclear what the effect of added mass combined with altered head positions would have on H-reflex amplitude. Head-supported mass and head position both have been loosely linked with changes in spinal height (Bonney & Corlett, 2002 and Hamalainen et al., 1996), but it is not clear whether these changes occur exclusively in the cervical spine or if they are distributed throughout the spine. H-reflex has been shown to be altered by changes in cervical spine nerve root space. It is unknown whether the addition of HSM, over a short period of time, would impart a load significant enough to decrease cervical spine nerve root space. While much of the existing research focuses on the signs and symptoms that aviators experience, the results of the proposed study can easily be generalized to all Soldiers and other occupations requiring long-term HSM use.

## **Statement of Purpose**

Aviators are known to experience chronic and acute neck pain and degeneration. Despite indications of nerve involvement, nerve function has not been assessed in relation to the combined effect of head-supported mass and head position. The purpose of this study was to determine if the H-reflex is a valid tool for determining the combined effect of head-supported mass and head position on nerve function.

## **Research Hypotheses**

1. In the flexed position, the H-reflex amplitude decrease in 2\_HSM will be greater than in 1\_HSM, and the amplitude decrease in 1\_HSM will be greater than in N\_HSM.
2. In the extended position, the H-reflex amplitude increase in 2\_HSM will be less than in 1\_HSM, and the amplitude increase in 1\_HSM will be less than in N\_HSM.
3. In the left rotated position, the H-reflex amplitude increase in 2\_HSM will be less than in 1\_HSM, and the amplitude increase in 1\_HSM will be less than in N\_HSM.
4. In the right rotated position, the H-reflex amplitude increase in 2\_HSM will be less than in 1\_HSM, and the amplitude increase in 1\_HSM will be less than in N\_HSM.
5. In the neutral position, the H-reflex amplitude in 2\_HSM will be less than in 1\_HSM, and amplitude in 1\_HSM will be less than N\_HSM.

6. There will be no change in H-reflex latency relative to baseline for HSM conditions.
7. There will be no change in H-reflex latency relative to baseline for head position.

### **Limitations**

1. Due to the specific inclusion/exclusion requirements and time availability, the sample size was small.
2. Exact head position recreation could not be guaranteed either within or between test days. Attempts to control head position via the InterSense InertiaCube™ were inconsistent. Participants were told to go to the end range of their maximum active range of motion.
3. The H-reflex is sensitive to changes in hydration, fatigue, exercise, and attention; none of these factors were explicitly controlled for in this study.
4. In order to determine the acute effects of mechanical nerve root compression due to head position changes and limited cervical spine loading the sample population was restricted to a young healthy population with no history of head-supported mass use or existing nerve pathology. The conclusions drawn from the data analysis are limited to this specific population.

### **Definition of Terms**

1. Electromyography (EMG) – Measurement of electrical activity in musculature through either indwelling or surface electrodes.
2. Hoffmann reflex (H-reflex) – Discovered in 1910 by Paul Hoffmann, it represents an electrically stimulated equivalent of the mechanical stretch reflex and serves as an assessment of alpha motoneuron excitability.

3. Amplitude (mA) – The most common variable analyzed with the H-reflex, it reflects the intensity of the resulting muscle contraction.
4. Latency (ms) – The time between stimulus artifact and the start of the H-reflex or motor-wave (M-wave). It reflects the time taken for the stimulus to travel the circuit and initiate the muscle contraction.
5. Helmet configuration – Variable mass and center of gravity offset for different experimental conditions.
6. Night Vision Goggles (NVG) – A visual device mounted to the front of the helmet which amplifies ambient light to allow the operator to see during little to no light conditions.
7. Head-supported mass (HSM) – A load carried on the head for an extended period of time. For the purposes of this study, it refers to the helmet and any added components.
8. Flexor Carpi Radialis (FCR) – A wrist flexor muscle located on the ventral medial aspect of the forearm. The FCR is a common upper-limb H-reflex testing site for the median nerve.
9. Active Range of Motion (AROM) – The total achievable distance through which a joint can be moved by activating joint specific musculature.
10. Muscle Activity – Muscle having measurable action potentials.
11. Gravitational force (g) – Acceleration of an object relative to free-fall.

### **Significance of Study**

Neck and back pain during flight are two of the most frequently cited complaints by aviators. Changes such as foraminal stenosis, osteophyte development, and disc degeneration are well documented in individuals with a history of HSM use. Nerve compression has been



linked with a decrease in H-reflex amplitude and can be exacerbated with positional changes of the head and neck. Awkward head positions combined with HSM are likely linked to long-term neuromuscular effects. To date, the acute effects of HSM and HP on nerve function and/or nerve root compression have been established. This study established the H-reflex as a possible measure of the acute effects of HSM on nerve function in different head positions. This effort will help justify use of the H-reflex in future studies as a metric to examine the acute physiological effects of HSM on aviator health and performance in a flight environment. The H-reflex will be a valuable metric for cervical nerve function with potential to be used in military medicine as an early diagnostic tool of degenerative changes. The H-reflex metric will also aid in establishing standards for helmet manufacturers and standards for return to duty following injury/surgery.

## **CHAPTER TWO**

### **Review of Literature**

#### **Injury Pathology**

It has long been known that neck and back pain are a particular issue in military personnel. There are many suppositions as to the root cause of this pain. The operational environment, required personal protective equipment, and job related physical tasks are all potential causes for such pain. Anecdotal reports from Soldiers and aviators indicate pain ranging from mild discomfort to severe and debilitating in severity and from acute to chronic, and either localized to one spot or diffuse across a body region. There is no question that pain is a major issue in today's military personnel. The full breadth of this issue in the US Army was best documented in a technical report covering neck and back injuries over a period of 22 years. The Total Army Injury and Health Outcomes Database (TAIHOD) was used to track hospitalizations, disabilities, unit reports of accidents, and outpatient visits for all active-duty soldiers between January 1, 1980 and December 31, 2002. Injuries were further classified by gender, age, rank, and as either acute or chronic. There were a total of 1,257,878 neck- or back-related injuries documented between 1980 and 2002. During this time period, 13.5% of neck- or back-related injuries in the enlisted population were neck injuries whereas 23.5% of reported injuries were neck-related in officers. Enlisted personnel were more likely to be hospitalized for injuries than officers (6.2/10,000 compared to 2.6/10,000). Neck-related injuries were responsible for disability evaluations in 1,124 enlisted personnel and 94 officers whereas back-related injuries were the cause of disability evaluations in 13,669 enlisted and 703 officers. There were 1,054,530 outpatient visits documented for neck- or back-related injuries. Neck pain

was responsible for the majority of visits (57,120) including intervertebral disc disorder (8,354), spondylosis with myelopathy (2,314), and segmental/somatic dysfunction (7,063). There were 1,124 neck-related disabilities for enlisted personnel. Thirty-one percent of these were for limited cervical range of motion (CROM), 21% for paralysis related to the 5<sup>th</sup> and 6<sup>th</sup> vertebrae, 31% for paralysis of all radicular groups, and a combined 9% for neuritis or neuralgia of the radicular groups. Similarly, there were 94 reported disabilities for officers with 34% for limited CROM and 32% for paralysis of all radicular groups. Approximately 12% were for neuritis or neuralgia of the radicular groups. There were 13,669 disability reports for enlisted 64% were due to lumbosacral strains and 24% were related intervertebral disc syndrome. There were 703 back-related disability evaluations for officers with 44% related to intervertebral disc syndrome and 42% related to lumbosacral strains. Receiving flight pay was the only significant indicator for hospitalization for neck injury amongst hazardous duty pay categories. Flight pay in officers and enlisted was associated with increased risk of chronic neck and back hospitalizations, outpatient visits, and acute back injury accident reports. In officers, flight pay was associated with an increase in disability reports (Amoroso et al., 2005).

Neck and back pain in military aviators has been of interest for a number of years due to the unique environmental exposures of this subpopulation. Prolonged whole body vibration, confined awkward postures over time, and long-term wear HSM are three of the particularly problematic aspects of the environment in which aviators operate. All have been studied as significant contributing factors to the onset of pain.

**Vibration.** Vibration has been studied as a potential cause of neck and back pain. Harrison et al. (2011) recorded incidence of neck pain and multiple physiological measures

in helicopter aircrew. Neck pain occurred in 53% of participants with no significant difference between pilot and flight engineer reporting rate. Harrison's group initially thought there would be a difference between flight role (pilots vs. flight engineers) and incidence of neck pain due to differing job tasks. The authors believed a common exposure, such as vibration, to both flight engineers and pilots is responsible for the consistent reporting of neck pain.

de Oliveira and Nadal (2005) examined the transmissibility of vibration from the helicopter into the pilots' spine. Two uniaxial accelerometers were affixed to the L3 and T1 spinous processes. Vibration was recorded during a two hr flight. The authors concluded that while there is evidence that there is resonance at T1 at the same frequency of the main rotor blade, the transmissibility of the vibration is not at a dangerous level. Another study examined the amount of vibration produced during landings in a Boeing 737. Tri-axial accelerometers were positioned under the front and rear cabin crew seats. The rear crew seat had higher mean values for z-direction leading the researchers to conclude that flight attendants sitting in the rear crew seat are at a greater risk for injury than those sitting in the front seat due to the increased repetitive shock produced during landing (Burstrom et al., 2006).

Wilder et al. (1982) examined the transmissibility of vibration through the spine in different positions. EMG activity was recorded as a scaled root mean square (RMS). The other variables examined were transmissibility, spinal system stiffness and fatigue. The results indicated that there was a progressive stiffening of the spine as the vibration frequency increased. Gender and changes in posture and muscle fatigue alter the transmissibility and spinal stiffness. Lateral bending and rotation decrease spinal stiffness and reduce transmissibility at lower

frequencies, while flexion increases stiffness. At higher frequencies stiffness decreases in flexion, extension, and rotation with concurrent increases in transmissibility. In comparison, females showed an increase in spinal stiffness in rotation and a decrease in transmissibility in right lateral bend. Performing the Valsalva maneuver caused varied changes on stiffness and transmissibility. When comparing males and females at low frequency, females had a significantly greater increase in stiffness and transmissibility. Fatigue caused a non-significant increase in transmissibility in males and a non-significant decrease in females. Stiffness increased in males and females as a result of fatigue with the only significant increase in males at low frequency. Vibration did not significantly affect EMG. The authors believed the gender differences were likely due to increase body mass, specifically variations in breast tissue within the sample population, and that vibration at low frequencies has the greatest potential for injury regardless of gender (Wilder et al., 1982).

Researchers compared erector spinae (ES) EMG recordings under vibration and no-vibration conditions to baseline levels in Brazilian Air Force male helicopter pilots. The researchers did not find a consistent effect of vibration on EMG activity on either the right or left sides. The researchers concluded that although vibration has been cited as a possible cause for low-back pain in aviators, the results of this test did not show any consistent effect of vibration on EMG activity either on the ground or during flight (de Oliveira et al., 2001)

Shanahan and Reading (1984) attempted to recreate low back pain experienced in flight in a laboratory setting. Eleven Army aviators (age  $30.4 \pm 3.9$  years) with a history of low back pain during flights of less than two hours (hrs) duration participated in the study. A mock-up of the helicopter cockpit was built and attached to the Multi-Axis Vibration Simulator (MAVS).

Each of the participants was tested twice, once with vibration and once without. Each simulation was 120 min in duration. There was no significant difference between test conditions for either time of pain onset or pain intensity. Using a 100 mm pain scale, average pain intensity experienced during the vibration condition was  $31.0 \pm 11.4$  mm and  $35.9 \pm 10.9$  mm for the no-vibration condition. Average time of pain onset was  $65.0 \pm 23.5$  min for the vibration condition and  $65.5 \pm 31.6$  min for the no-vibration condition. The researchers concluded that the onset of pain and pain intensity was most likely related to the posture required of the aviators during flight rather than the vibration experienced.

The literature is inconclusive on the direct impact of vibration on pain. It is clear that vibration at different frequencies is transmitted through the spine and may in fact lead to long-term injury. However, muscle activity does not appear to be directly affected by vibration, nor is there a clear link with vibration and onset of pain. The general opinion is that vibration may be a minor contributing factor, but posture is likely the predominant cause of pain in this environment.

**Posture.** Military aviators are somewhat unique in that their specialty requires them to operate in the confined spaces of a cockpit over long mission periods with little opportunity to stretch or adjust their body positions. Restricted posture has been shown to be a cause of neck and back pain in civilian populations particularly with office workers. Cagnie et al. (2007) examined the incidence of neck pain in office workers over the course of a year. A questionnaire covering physical and psychosocial work characteristics and individual characteristics was distributed to 512 computer users (225 females, 287 males; age 20 – 59 years). The results showed that the most significant predictors of neck pain were holding the head in a flexed

position for long periods of time, holding the head in the same position for long periods of time, making the same movements repeatedly, and very short periods of movement of the head. Other significant predictors of neck pain were computer time of more than four hrs/day, and sitting for a long period of time. The posture assumed when looking at a computer is similar to that required of aviators looking at a cockpit instrument panel.

In a review of literature, Pelham et al. (2005) described the various causes of low-back pain in aviators. The authors determined that the predominant cause of low-back pain was most likely the forward flexed and laterally rotated position that aviators are required to maintain during flight. The seat back has a greater angle than the trunk causing the pilot to maintain a constant isometric contraction and placing the musculature of the low-back in a continual stretch position. Due to the location of the controls, the pilot must also rotate to the left to properly control the cyclic. The left hand is controlling the collective, and must also be in a constant near isometric contraction. Neither arm is supported unless propped on the knee during flight. The feet are unstable due to the location of the rotor pedals. Because the feet are constantly moving to adjust for rotation, they do not support the weight of the body at all and are not able to aid in the dispersion of vertical forces placed on the body. The increased forward flexion of the trunk forces cervical extension particularly when wearing night vision goggles (NVG) causing continual isometric contraction of the cervical extensors. Constant muscle contraction is known to increase fatigue and potentially cause pain.

An Australian study surveyed all military rotary wing pilots on the incidence, severity, and relationship of back pain to flight time. The results showed that of those that responded, 16% suffered regular back pain, 28% suffered back discomfort, and 39% suffered occasional

back pain. Of these, 86% of the pain was located in the low-back, 21% in the mid-back, and 25% in the buttock. Twenty-five percent reported pain in the neck and 8% reported pain in the shoulders. Pain was typically reported to begin after two hours of flight. The duration of pain lasted between 30 to 60 min for 40% of the respondents and between 1 to 4 hrs for 22% of the respondents. There were no significant relationships between pain and any anthropometric measures. Those with a previous back injury were significantly more likely to report back pain and history of back injury was the only significant predictor of back pain. Those pilots complaining of neck pain had flown significantly more hours than those not complaining of neck pain (1415 hrs vs. 1028 hrs). Back pain contributed to a loss of concentration in 54% of respondents, and 16% reported rushing a mission due to pain. Aircraft platform seemed to be heavily linked to incidence of pain with some showing 75 -95% of pilots reporting pain (Thomae et al., 1998).

A similar study was conducted with the British royal navy. Questionnaires were distributed to all 246 rotary wing pilots. The questionnaire included topics such as flight experience, medical history, aircraft ergonomics, musculoskeletal pain as pilot, musculoskeletal pain as the co-pilot, self-assessed flying posture, and various psychosocial factors. There was a 76% response rate. There was no link between back pain and anthropometric variables or flying time. Of the respondents, 80% reported low-back pain, 48% reported neck pain, and 29% reported sciatica while in the pilot role. There were significantly fewer reports of neck pain and sciatica (32% and 22%, respectively) in the co-pilot role. Of those reporting back pain, 66% reported that the pain interfered with duty, and 12% reported missing work because of the pain. Posture varied significantly according to the type of flying; instrument, visual forward, or



prolonged hover. The reported level of back pain was significantly higher during visual forward flight and prolonged hover when sitting in the slightly forward posture than when sitting upright. During instrument flight, the reported level of back pain was significantly higher when sitting far forward than when sitting slightly forward. When in the co-pilot role, the level of back pain did not differ relative to posture. Lateral tilt and trunk rotation were significantly lower in the co-pilot than in all other flight types as pilot. The ergonomic aspects of the aircraft and seat most commonly referred to as causing pain were seat angle, seat shape, seat adjustability, seat padding, shape of back cushion, and operational posture (Bridger et al., 2002).

Posture appears to be one of the most consistent contributing factors to incidence of neck and back pain. Regardless of the type of aircraft, aviators are required to adopt very restrictive postures during flight with little opportunity to stretch or adjust. The addition of HSM adds additional strain particularly to the back of the neck. Individual flight tasks require different levels of muscle activation and postures which lead to increased pain.

### **Spine Degeneration**

Regardless of the root cause of back and neck pain in aviators, there is little doubt that long-term musculoskeletal effects are occurring. Froom et al., (1984, 1987a, and 1987b) were successful in documenting the incidence of back pain and spinal degeneration in aviators. Their group found that helicopter pilots were more likely to have spondylolisthesis than a control group of non-pilots as shown in x-rays (1984). In a follow-up study, the group tracked pilots of different aircraft type with and without low-back pain (LBP) and spondylolisthesis. There were nine participants with spondylolisthesis but no LBP. There were 12 participants with spondylolisthesis and LBP. These 12 were age and aircraft matched to 12 participants with LBP

but no evidence of spondylolisthesis. All of the participants were tracked for 12 to 131 months (mean 38.6) for increased incidence of LBP and increased evidence of spondylolisthesis. None of the nine asymptomatic pilots with spondylolisthesis had an increase in symptoms. Four of the symptomatic spondylolisthetic participants had an increase in symptoms compared with three of the symptomatic non-spondylolisthetic participants (1987a). Job task during flight seems to be significantly linked to onset time and severity of pain. Pain onset was much sooner in the pilot seat ( $85 \pm 32$  min) compared to the gunner seat ( $109 \pm 31$  min). The intensity level of the pain reported was significantly higher in the pilot seat than in the gunner seat. The pain onset time was also significantly sooner in the pilot seat (1987b).

Cervical spine anatomy has often been studied as it relates to neck pain. Congenital variations may predispose individuals to pain. These congenital variations may also exacerbate or accelerate degenerative changes frequently documented in individuals complaining of pain. Grob et al., (2007) studied the curvature of the cervical spine relative to reported neck pain in civilian males and females. The cervical (C) spine (C2 to C7) was examined and classified as having a lordotic ( $< -4^\circ$ ), straight ( $-4$  to  $+4^\circ$ ), or kyphotic ( $> +4^\circ$ ) curvature. Data were then compared to frequency of neck pain and whether the neck pain caused difficulty with sleeping, work, leisure activities, housework, caused participants to seek medical attention, or use over-the-counter medications to treat the neck pain. There were significantly more kyphotic segments found in the pain group compared to the no pain group. This was typically found in the C3-C4, C4-C5, and C5-C6 segments. These changes in spinal curvature may lead to cervical nerve root compression and increased pain. Pathology at the C6-C7 level has also been linked with

increased headaches. Perrson et al. (2007) found a significant decrease in headaches and radicular symptoms after a nerve root blocks at C6 and/or C7.

A study out of Japan examined magnetic resonance imaging (MRI) scans of both males and females ranging in age from 10 to over 60 years. Posterior disc protrusion was significantly more common in males over 40 than in females. Foraminal stenosis was more common after the age of 50 and significantly more common in males than in females. Overall, age was a significant predictor of presence of degeneration and other variables (Matsumoto et al., 1998).

An older study compiled data from 16 previously published reports which examined spinal disc degeneration relative to age and gender. A total of 600 discs were analyzed coming from 273 spines. This was further broken down to 363 discs from 161 male cadavers (age  $45.44 \pm 18.15$  years) and 237 discs from 112 female cadavers (age  $46.39 \pm 20.26$  years). Male cadavers were significantly more likely to have disc degeneration at an earlier age with the first evidence of degeneration occurring in the first decade in males and not until the second decade for females. Females tended to show signs of degeneration by severity approximately a decade after males did. However, by age 70, there were no significant differences between sexes with respect to presence of significant disc degeneration. There were significant differences in degeneration between L1-L3, L1-L4, L2-L3, and L2-L4 (Miller et al., 1988).

Degenerative changes, in all regions of the spine, have been documented in military aviators, though the bulk of the literature documenting such degeneration is focused on fixed wing high g environments such as fighter pilots. Petren-Mallmin and Linder, (1999) examined MRI scans for evidence of disc degeneration in asymptomatic fighter pilots with different levels

of experience (cumulative flight time) and age-matched controls. Participants were graded on disc protrusion/herniation, posterior vertebral border osteophytes, spinal cord compression, foraminal stenosis, disc height, and signal intensity. Experienced pilots had higher incidence of osteophytes, disc protrusion/herniation, spinal cord compression, and foraminal stenosis than other groups. A follow-up study compared the previous results to new MRI scans. Experienced pilots showed a significant increase in disc protrusion/herniation and foraminal stenosis. The control group also showed significantly higher mean scores for disc protrusion/herniation and osteophytes compared to the previous results. The young pilots also had a significant increase in mean scores for disc protrusion/herniation and osteophytes and a significant decrease in signal intensity compared to earlier scans. The experienced pilots again had significantly higher mean scores for disc protrusion/herniation, osteophytes, spinal cord compression, and foraminal stenosis than the control groups for the current scans (Petren-Mallmin & Linder, 2001).

Hamalainen (1993) compared fighter pilots to non-pilot controls for evidence of cervical spine disc degeneration. Disc degeneration and bulging were graded on a scale of zero to six with zero being normal and six being disc bulging and compressing the spinal cord. The pilots had a higher rate of occurrence of disc degeneration at all levels except C5-C6 with C3-C4 being the most significant.

Fortunately, comparative studies exist that track differences in degeneration between fixed wing high and low g and rotary wing aviators. Landau et al. (2006) evaluated cervical and lumbar disc health in three different groups of pilots. Helicopter pilots (HP), fighter pilots (FP), and transport pilots (TP) were evaluated by MRI. Cervical degeneration was found in 16 of the 29 participants with a total of 27 discs showing central disc protrusion at C5-C6 (13 total; 7 TP,

3 HP, and 3 FP); C6-C7 (10 total; 5 TP, 3 HP, and 2 FP), C4-C5 (4 total; 2 TP, 1 HP, and 1 FP), and C7-T1 (1 TP). Transport pilots were significantly more likely to have a cervical disc protrusion than FP and there was a trend toward these protrusions being more severe. Lumbar degeneration was found in 18 of 30 participants 17 of which showed disc protrusion.

Similarly, Aydog et al. (2004) retrospectively examined the history of cervical and lumbar changes in pilots of various types of aircraft. Medical records and MRI images were analyzed for presence of cervical and lumbar changes. HP had a significantly higher prevalence of cervical osteoarthritic changes than other pilot groups and the non-pilot control group. All groups showed significantly more compression fractures in the lumbar than cervical region. Age was the best predictor of presence of cervical and lumbar changes. There was a large variability in the average amount of flight time within groups, but no effort was made to relate spinal changes to amount of flight time.

One of the most comprehensive studies tracked 359 symptomatic pilots in the German armed forces documenting the prevalence of both lumbar and cervical disorders. Helicopter pilots had a higher incidence of cervical pathology (33 cases) than jet or transport pilots (24 and 22, respectively). Symptoms typically took longer to present in helicopter pilots than jet or transport pilots (4000 flight hrs vs. 1825 and 1970 hrs, respectively). In the helicopter pilots with cervical pathology, 20 experienced radicular symptoms, four experienced radiating symptoms, and nine had localized symptoms (Pippig & Kriebel, 2000).

While the incidence of spinal degeneration over time is well documented, there is less documentation of the acute changes and injuries that occur in aviators. A Norwegian study

examined x-rays of 232 flight candidates and found that there were 141 abnormal findings in the cervical spine, 173 in the thoracic spine, and 213 in the lumbar spine. Anomalies were almost entirely isolated in the lumbar spine. Degeneration was almost twice as likely to occur in the thoracic spine as the cervical or lumbar regions. There was evidence of Schmorl's nodes (micro-herniation of the nucleus pulposus) in approximately 15% of the thoracic and lumbar spine films. There was an 18% occurrence of reduced disc height. There was a 5.2% rate of spondylolisthesis (Anderson et al., 1991). A number of case studies highlight the extent of the acute injuries which can occur in a high g environment. Hamalainen (1994 and 1999) documented multiple fighter pilots presenting with acute onset of pain, numbness and tingling in the fingers, loss of cervical range of motion, and muscle weakness. MRI, computerized tomography (CT), and x-ray revealed evidence of numerous conditions including disc degeneration, disc prolapsed, osteophytes, stenosis, spondylosis, and spondylarthrosis. The vertebral segments most often affected were C4-C5, C5-C6, and C6-C7.

### **Head-Loading and Spinal Changes**

**Chronic effects.** Degeneration is apparent in all populations over time, but seems to be accelerated in military populations, particularly aviators. A likely link to this accelerated degeneration is spinal loading. In military populations, spinal loading can occur from operating in high g environments as discussed previously, or from carrying a load directly on the head, as in the helmet and attached technologies.

Extreme cases of load carriage on the head, as in Zimbabwean porters, have been linked with spinal degeneration over time. Zimbabwean porters who carry loads on the head as a primary means of transportation were compared to non-porters ranging in age from 10 to 70

years. X-rays showed a significant decrease in angle of lordotic curve in both porters and non-porters when comparing 20-30 year olds to 30-40 year olds. The decrease was significantly greater in the porter group and continued gradually each decade (Joosab et al., 1994). The amount of load carried on the head coupled with the length of time it is carried may accelerate spinal degeneration. A different study of porters further categorized them by amount of load carried on the head and calculated a lifetime stress score. Participants were 35 porters (27 male, 8 female) divided into either the 20-39 age group or the 40-59 age group and 35 age and sex matched non-porter controls (nCA). Porters were classified as either heavy-load carriers (H-CA;  $\geq 150$  kg x years), or light-load carriers (L-CA;  $< 150$  kg x years). Lateral x-rays were taken of the C4-C5, C5-C6, and C6-C7 segments for each participant. Each x-ray was examined for presence of osteophytes, decrease in vertebral body height, and disc height. A total lifetime stress score was calculated for presence of degenerative changes. Of the porters, 88.6% showed presence of degenerative changes compared to 22.9% of non-porters. Both age groups showed significantly greater percentages of degenerative change in the porter group vs. the non-porter group. The majority of the changes occurred in the C5-C6 (80%) segment with the C4-C5 and C6-C7 segments each having approximately a 50% prevalence of change. The H-CA had significantly greater prevalence of change than did the L-CA. Shrinkage of at least one of the vertebral bodies occurred in five of the H-CAs (C6, C5, and C4) (Jager et al., 1997). This is supported by a study by Masuoka et al. (2007) who used cadaver spines from a rat to determine the difference between cyclic versus compressive loading. The authors determined that the most important factor in disc height loss was the peak load and not the averaged load over time (Masuoka et al., 2007).

**Acute effects.** Awkward postures held over time, and long-term spinal loading have been shown to contribute to both pain and detrimental musculoskeletal effects. It is easy to make a link between chronic spinal degeneration/disc compression and pain whether it originates from position or HSM, or a combination of all factors. What is more difficult is to determine if short-term exposure to any of these factors is significant enough to initiate a pain response. There is limited research demonstrating that both posture and spinal loading can cause a measurable change in overall height. Bonney and Corlett (2002) examined changes in spinal length following an hour with the head held at specific angle with the body held in a set posture. Seven males (mean age 21.6 years) participated in the study. Each participant was tested on three different days. Height was measured before and after the participant watched an hour long video. A precision stadiometer was used to ensure that the participants held their heads at the specified angle. Head angles of 0°, 20°, and 40° were randomly assigned for each day. There was a significant decrease in height following the hour held at both 20° and 40°, but not at 0°.

A similar study found that aviators experienced a decrease in height in a relatively short period of time. The study looked at 20 aviators (age 22-28 years) early in their careers (63 – 800 flight hours) and examined height using displacement transducers and a force plate under flight and non-flight conditions. The flights consisted of an aerial combat maneuver exercise (mean duration 41 min) with a mean g exposure peak of 7.2 g. For the flight condition, measurements were taken pre-flight standing, after 30 min in the psoas position (supine with both hips and knees flexed at 90°), and immediately post-flight. The non-flight condition measurements were made standing, after 30 min in the psoas position, and immediately after sitting in the aircraft with full gear for 30 min. The results showed a significant decrease of body height (- 4.9 mm)



from pre-flight to post-flight measurements. Lying in the psoas position increased height by 2.5 to 3.5 mm. This height increase was normalized after sitting in full gear for 30 min (Hamalainen et al., 1996). This height change is no doubt spread across the length of the spine, and is within the limits of normal diurnal variation in height (19 mm; 1.5 mm per disc) (Adams, et al., 1990). However, this must be qualified by the fact that the change in height occurred acutely after only 30 minutes time passed and with exposure to a high g spinal load.

Adams, Dolan, Hutton, and Porter (1990) further explained the effects of short-term (24 hrs) variation in height as it relates to pain. The discs are at their fullest height in the morning and it has been shown that the segmental nerve roots are stretched at this point. As the disc height decreases throughout the day, the height of the intervertebral foramen decreases. The authors suggest that this nerve root compression could cause an increase in lumbar back pain particularly during backward bending or in an increased lordotic posture due to increased loading of the apophyseal joint surfaces.

Military helmet mass and center of gravity offset vary greatly and are affected by helmet size, type, and position of technology mounted on the helmet (e.g. night-vision goggles; deployed or stowed), ground Soldier vs. vehicle operator, and type of vehicle or aircraft. These helmet systems are often worn for hours while the Warfighter is performing their specified job task. This could require whole body movements such as running and jumping, or be isolated to head/neck complex specific movements such as in aviation which requires large range of motion movements of the head and neck during aircraft operation. A survey of Army aviators tracked demographics, aviation history, frequency and severity of spinal symptoms, history of spinal injury, treatment of existing spinal conditions, medical waivers, and self-prescribed exercises or

preventive measures for spinal pain. Respondents were classified by flight time with head mounted systems as high (having more than 300 hours) and low (having less than 300 total flight hours with the system). The respondents all wore one of four standard issue helmets. The high group had an 86% reported incidence of some type of spinal pain and the low group had a 73% reported incidence rate. Approximately 50% of the participants reported experiencing symptoms monthly or more often and almost 30% reported symptoms weekly or more often. The high group was significantly more likely to experience weekly symptoms than the low group. The pilots reported the symptoms most likely resulted from helicopter ergonomics, flight mission length, and helmet mounted systems (Hiatt, 2000).

### **Head-Supported Mass**

Head-supported mass is traditionally studied as it relates to increased injury risk and vigilance or ability to complete job-specific tasks. In a comprehensive study conducted at the U.S. Army Aeromedical Research Laboratory (USAARL), researchers studied the effects of various combinations of helmet weight and location of head supported device center of mass offsets (CM-offsets) in females during whole-body vibration (WBV). Twelve different helmet configurations, three weights and four CM-offsets, were used for the study. Data were also collected for each participant with no helmet to be used as a reference. The helmet weights were 2, 3, and 4 kilograms (kg). CM-offsets were 2 centimeters (cm) behind (-) the atlanto-occipital complex (AOC), 0, 2, and 4 cm in front of the AOC. Four accelerometers were fixed to a 12 cm bite bar to measure acceleration in the anterior-posterior (A-P) and axial movement of the head. The multi-axis ride simulator (MARS) system was equipped with a UH-60 seat. The MARS system produced vertical WBV in a ramp up ramp down method from 2 to 17 Hz at a rate of

0.25 Hz/s with the entire sequence lasting approximately two min. The researchers found that magnitude of pitch acceleration, axial acceleration and anterior posterior acceleration were affected by CM-offset and helmet weight.

CM-offset was associated with differences in axial acceleration and pitch acceleration. Helmet weight alone was associated with differences in A-P acceleration and pitch acceleration magnitudes. Helmet weight moment was linked with differences in magnitude of pitch acceleration, axial acceleration, and A-P acceleration. There was a significant interaction effect for CM–offset and helmet weight for pitch acceleration. Pitch acceleration was significantly different in the 4 kg helmet weight across CM-offset from the 2 kg helmet and marginally different from the 3 kg helmet. Likewise, the 3 kg helmet was significantly different from the 2 kg helmet. Pitch acceleration was marginally significantly different in the 4 cm offset across all helmet weights from the 0 cm offset but not significantly different from any of the other CM-offset. When normalized by the unloaded condition, there was a significant difference in pitch acceleration between helmet weights. There was a significant interaction effect between helmet weight and CM-offset on normalized pitch magnitude. When compared to a similar study of male participants, differences were found. However, the researchers did not recommend alterations of helmet design specifications based on gender (Barazanji & Alem, 2000).

A related study at USAARL analyzed flight performance with varying amounts of HSM and locations of CG. Five different combinations of helmet mass and CG were used for the study. Each helmet combination could be described by the weight-moment, expressed in Newton centimeters (N-cm), which is the product of the weight and the distance between the CM and the external auditory meatus (EAM). Eight of the participants wore four different weight-

moment helmets once in four different flight simulations in a simulator. A separate helmet/CG combination was designed to be a mid-point for helmet weight and CG location. This helmet was worn by the ninth participant in the same flight simulation. Each combination was tested on a separate day. The flight simulation iteration consisted of an instructor pilot directed traffic pattern and nap of the earth (NOE). There were six iterations completed for each helmet combination. Each flight was graded according to a standard scoring system. There was a significant effect of helmet combination on NOE performance. There was a significant effect for time on landing scores. The landing scores on the final iteration were significantly lower than those for the previous iterations. CG appeared to be the best predictor for performance with the CG located further away from the head resulting in significantly lower scores (Fraser et al., 2006).

Alem, Meyer, and Albano (1995) examined the effect of duration, helmet weight moment, and target location on vigilance during whole body vibration. The participants were tested during four different sessions each with a different weight moment (20, 110, 200, and 290 N-cm). The participants completed a series of tasks designed to measure the tracking ability, target acquisition speed (vigilance), and cognitive ability. These tasks and a rest period comprised one cycle. The participants completed 16 iterations of the test cycle with one 5-10 min break in the middle for a total test duration of four hrs. The targets were located in a square formation 5.4 meter (m) wide by 1.1 m high set 3 m in front of the participants. The results indicated that vigilance decreased as weight moment increased with the exception of the 110 N-cm configuration which had a greater vigilance rate than the 20 N-cm configuration. The authors

believed that the increased mass from the 110 N-cm configuration actually made the helmet more stable and served to dampen the vibration.

Butler and Alem (1997) studied the effects of helmet weight moment on neck acceleration during whole body vibration in rotary wing aviators. The participants wore each of four helmet configurations with weight moments of 123, 150, 280, and 410 N-cm during four hours of whole body vibration similar to that produced by a UH-60 helicopter. Pitch motion, X motion, and Z motion were measured via motion capture. The results indicated that there was no effect of exposure duration on pitch, X or Z motion. There was a significant effect of helmet configuration on pitch, X, and Z motion, with the higher weight moments showing significantly more motion than the lower moments. This is supported by Merkle et al. (2005) who found that impact speed and helmet weight were the two most implicated factors in increased neck injury during frontal impacts. Follow-up tests at a fixed impact velocity showed helmet weight correlated strongly with extension moment, shear, and tension forces. Horizontal CG placement also correlated strongly with extension moment. In other words, increased mass and CG placement correlate with increased injury risk.

### **Neck Strength**

In addition to increased injury risk, studies have examined the effect of spinal loading on from HSM or g on muscle activation and fatigue. Harrison et al. (2011) found a significant increase in both extension maximum voluntary contraction (MVC) and time to fatigue when compared to flexion in Canadian Forces helicopter aircrew. They also found left lateral flexion MVC to be significantly higher than right lateral MVC. This is likely due to job tasks and position in the aircraft. The crew reported  $1318.5 \pm 1128.5$  hrs total flight time;  $1047.2 \pm 943.5$

hrs of helicopter specific experience;  $123.2 \pm 119.1$  hrs NVG time with longest NVG mission length of  $3.1 \pm 1.8$  hrs.

One of the neck injury prevention techniques taught to fighter pilots involves bracing the head against the airframe. Green and Brown (2004) examined the level of muscle activation and position of the head during combat flight maneuvers. The aviators (mean 3025 hrs; cumulative flight time range 2200 to 4100 hrs) were examined during a 50 min simulation with 3-5 min combat engagements in an aircraft simulator. Surface EMG data were collected for the left and right sternocleidomastoid (SC) and the left and right erector spinae (ES). MVC was recorded for left and right lateral flexion (SC) and extension (ES) before and after the flight simulation. In cockpit video was used to record head position during the simulation. There was a strong linear relationship between ES activation and acceleration in the neutral head position. Head extension of greater than  $61^\circ$  was significantly associated with higher ES activation and SC activation. The head was positioned other than neutral (extended or extended and rotated) 68% of the time. ES was activated 40 to 80% of MVC during extension. This was reduced when the head was braced against the canopy. The ES muscle was activated at 40% of MVC for approximately 25% of the flight. There was a 35% overall reduction in MVC strength following the flight. There was a significant reduction in SC MVC and a trend toward significance in the ES. This is likely due to muscle fatigue from extreme muscle activation during flight.

A related study examined muscle activity in helicopter pilots and the effect of HSM and head position. All pilots were tested in various sitting positions while wearing either a helmet (1.45 kg), helmet and night vision goggles (NVG, 0.76 kg), or helmet, NVG, and counter-weight (CW, 0.33 kg). The positions tested were neutral  $0^\circ$  trunk inclination, rotation, and neck flexion;

0° rotation with 20° trunk inclination; 0° rotation with 20° neck flexion; all of the previous three positions with either 30° left rotation or 30° right rotation. All positions were held for five seconds. Surface EMG electrodes were attached over the left and right splenius capitus, the left and right erector spinae, and the left and right trapezius. MVC values were obtained for the muscles tested. Two goniometers were attached to the helmet to measure head position. The mean activity for all positions was significantly higher in the upper neck muscles when wearing the helmet and NVG and the helmet, NVG, and CW than when wearing the helmet alone. There were no significant differences in muscle activation between any of the conditions when the different positions were separated. Neck flexion with rotation and trunk inclination with neck rotation both showed significantly greater activation of the upper and lower neck musculature than most of the other positions. The left upper neck was activated significantly more during left rotation and neck flexion and left rotation and trunk inclination than the right upper neck muscles were during the same movements with right rotation. There were no correlations between muscle activation and any anthropomorphic measures or flight time (Thuresson et al., 2003).

Hamalainen and Vanharanta (1992) found that muscle strain of the erector spinae muscles increased from 5 to more than 95% of MVC during high g maneuvers with the head in different positions. Increased helmet mass can increase this muscle strain. Hamalainen (1993) found that mean EMG activity of the erector spinae tended to be greater during high g maneuvers when wearing a standard weight (~1.90 kg) helmet versus a lighter one (1.31 kg). Phillips and Petrofsky (1983) found that cervical muscle endurance in right lateral flexion decreased significantly from a 0 lb control with added mass in different center of gravity orientations.

Another study examined the effects of helmet weight and location on pain and muscle activity in non-aviators while conducting a repetitive tracking task with different amounts of HSM. The test conditions were as follows: normal (no helmet), helmet, helmet + 0.5 kg, helmet + 1 kg, and helmet + 2 kg for the front-mounted group, and the same conditions with the addition of an equivalent weight added to the back of the helmet for the counterbalanced group. Generally, there were significant increases in surface EMG in the front-mounted conditions as load increased. Neck extensor activity increased in flexion, left and right rotation, and decreased during extension indicating eccentric activation was required as the load increased forward of the head's center of mass. Similarly, sternocleidomastoid activity increased during extension with the front-mounted conditions. The counterbalanced condition showed more equal muscle activation in all positions as load increased. Ratings of perceived pain (PP) increased steadily with the addition of weight for most conditions and positions in both the front-mounted and counterbalanced groups and were significantly different from the normal condition. Generally, there was a significant increase in PP post-test in all conditions and positions in both groups. The counterbalanced group had significantly higher PP in the extended position in the helmet + 1.00 kg and helmet + 2.00 kg conditions when compared to the front-mounted group (Knight & Baber, 2004).

It is evident that acute and chronic neck pain, injury, and degeneration are an issue in today's military personnel, especially aviators. While much of the focus in previous research has been on pilots operating in high g environments, there is little doubt that the issue is of concern in helicopter pilots as well. Posture and HSM seem to be the likely contributors to increased risk of injury with both acute and chronic issues. What is not known, and very little effort has been



made to determine, is the effect the combination of these two factors can have on nerve tissue acutely.

## **Nerve Conduction**

The evidence of pain, paralysis, radiating, radicular, and localized symptoms in neck, shoulders, and arms imply nerve involvement. There are numerous different ways to test nerve function in the extremities. Nerve conduction testing has been used to test function degradation resulting from carpal tunnel syndrome, nerve impingement, and polyneuropathy among other things. Nerve function can be tested in a variety of ways; vibrotactile sensation testing, gap detection, quantitative thermal sensation testing, nerve conduction or velocity testing, and the Hoffmann Reflex are just a few of the viable options. Vibrotactile testing, gap detection, and thermal sensation all test the nerve's function via measuring its ability to "function normally". Nerve conduction/velocity and the Hoffmann Reflex measure quantitatively the nerve's ability to transmit a signal via amplitude or latency.

Vibrotactile sensation testing or vibration threshold testing (VTT) is a form of testing that has been used to assess viability of the sensory nerves. It has been used in office workers to determine if chronic keyboard use decreases the ability to detect vibration at the fingertips (Sanden et al., 2005), in gerontology to quantify sensory loss with age (Era et al., 1986), and quite successfully with carpal tunnel syndrome.

One such study compared two methods of testing vibration perception thresholds (VPT) in participants with varying degrees of neuropathy. There were a total of 478 participants (control n = 52, diabetes mellitus without neuropathy (DM-NP) n = 81, DM with mild

neuropathy (DM-miNP n = 94, DM with moderate neuropathy (DM-moNP) n = 109, and DM with severe neuropathy (DM-sNP) n = 142). The Neurothesiometer was compared to the CASE IV. The Neurothesiometer used the limit method described previously to determine VPT. The CASE IV uses the step down 4-2-1 method. In this method, the stimulation is started in the middle and decreased by four units; if the participant could still feel it then the stimulus was decreased by another four units. If the participant could not feel the stimulus at this point then the stimulus was increased by two units. If the stimulus could be felt at this point, then it was dropped by one unit. This technique was continued until the lowest level was determined that the participant could barely discern the stimulus. This point was established as the just noticeable difference (JND). All vibration testing was performed on the left great toe. Prior to testing, each participant was graded on the presence or absence of diabetic sensorimotor polyneuropathy (DSP) which included measures of symptoms, reflexes, and a physical examination. The reference group was significantly younger than any of the other groups. There was also a significant difference in how long ago the participant had been diagnosed with DM and DSP. VPT increased proportionally with the increase in severity of DM-NP when tested by either piece of equipment. VPT for DM-sNP was over seven times that of the DM-NP group ( $147.6 \pm 91.5$  and  $22.4 \pm 30.9$ , respectively). The authors reported that both types of equipment were sensitive enough to determine DSP, but the Neurothesiometer was more sensitive than the CASE IV (Bril & Perkins, 2002).

Winn et al. (2000) sought to compare results from both nerve conduction testing (NCT) and VTT on the same participants and across different age groups and hands. All of the participants in the CTS group had CTS in their right hand which was their dominant hand. VTT

was measured using a tactile stimulator from an Optacon viewer. The matrix for the stimulator contained 144 rods spaced 2 mm apart horizontally and 1mm apart vertically. The vibration frequency was set at 230 Hz. White noise was used to mask the noise produced by the equipment. The median nerve was tested at the second finger and the ulnar nerve was tested at the fifth finger. NCT was measured using surface electrodes and a supramaximal square wave stimulus. Conduction velocity, or distal latency, between the wrist and elbow was calculated as the time between peak stimulus at the wrist and the beginning of the action potential in the hand. Velocity was recorded as latency divided by distance measured. Amplitude was measured using an oscilloscope.

There was a significant difference VTT in the median nerve between the control group and the CTS group on both hands. There were significant differences between the 20-29 age group and the 40-49 and the 50 and older groups on VTT for the median nerve on the individual hands. There was a significant difference in VTT for the ulnar nerve on the left hand between the CTS group and the control group. There were no other significant differences for the ulnar nerve. NCT also showed a significant difference in the median nerve in the individual hands between the CTS group and the control group. There was a significant difference in latency between the median and ulnar nerves. There were significant differences found between the groups on mean velocity for both median nerve motor function and median nerve sensory function. As with VTT, NCT velocity showed a significant difference between the youngest age group and the two oldest age groups for median nerve motor function on individual hands. NCT amplitude showed a significant difference between groups for median nerve sensory function for the individual hands. The ulnar nerve showed a significant difference between groups only for

the left hand. There were significant differences between age groups for both hands combined on median nerve motor function with the younger groups showing significantly higher amplitudes. There was also a significant difference in age groups for the ulnar nerve sensory function amplitude for the hands combined and for the right hand individually (Winn et al., 2000).

Burns et al. (2002) compared clinical vibration impairment (CVI) with quantitative vibration testing (QVT) in three neuropathy study cohorts. The three cohorts were: Peripheral Nerve Center (PNC; n = 166), ASTA Medica, Inc. (AM; n = 374), and the Rochester Diabetic Neuropathy Study (RDNS; n = 247). CVI was tested with a tuning fork on the patient's great toe. Participants were also evaluated on age, gender, and anthropomorphic classification. Each cohort also filled out a neurological assessment form (Mayo Clinic Neurologic Record Sheet for PNC and the Clinical Neuropathy Assessment (CNA) form for AM and RDNS). QVT was tested using the Computer Assisted Sensation Examination IV (CASE IV) which tests vibration, cooling, and heat-pain threshold. QVT used the standard 4-2-1 step-down algorithm which includes null stimuli. All measurements were classified as either 0 – normal, 1 – mildly elevated, or 2 – markedly elevated for CSI and QVT. All participants were further divided into four percentile groups of abnormality according to scores on the QVT evaluation. Each cohort was compared on the basis of percentage of abnormality and score on the tests. The RDNS cohort was further evaluated using a composite technique known as  $\Sigma 5NC$  which is a measurement of the severity of nerve conduction abnormality.  $\Sigma 5NC$  was compared with CSI and QVT in the four percentile groups. There were significant correlations between CSI and QVT in all three cohorts in all percentile classifications. CSI tended to overestimate the degree

of abnormality in the PNC and AM cohorts across all percentile levels of abnormality. In the RDNS cohort, CSI tended to underestimate degree of abnormality in the lower three levels of abnormality, but was fairly accurate with classification in the highest percentile of abnormality. Age and body surface area (BSA) accounted for roughly 25% of the variability between the CSI and QVT in all percentile groups of abnormality in the PNC cohort. Age, BSA and height accounted for approximately 5% of the variability in scores across percentile groups in the AM cohort. Age was the only factor that significantly accounted for variability (~ 10%) in scores across percentile groups in the RDNS cohort. The correlation between QVT and  $\Sigma 5\text{NC}$  was significantly higher than that between CSI and  $\Sigma 5\text{NC}$ . The researchers concluded that physicians should take into account age, height, and BSA when utilizing CSI as a diagnostic technique. It is important to also utilized null stimuli and varying levels of stimuli to accurately diagnose level of impairment.

Gap testing uses a gauge to measure a minimum detectable gap by individuals. As sensory nerve function deteriorates or is impaired, the minimum detectable gap increases. Radwin et al. (2004) used gap testing to gauge recovery from carpal tunnel release surgery before and after carpal tunnel release surgery. All participants served as their own control having only one hand operated on. All participants completed a questionnaire indicating the severity and frequency of symptoms, occupation, and pertinent medical history at both the pre- and post-surgery (six weeks post-op) testing session. Sensory testing was performed by a graduated algorithm in which the participant had to detect incremental changes in gap on a test platform. The upper level gap size and the smallest detectable gap size were averaged to give a gap detection threshold. The second and fifth fingers were tested. There was a significant

decrease in gap-detection threshold for the second finger following surgery. There was a significant decrease in gap-detection threshold for the fifth finger as well post-surgically. There was no significant improvement in either finger in the non-surgical hand. There were small but significant correlations between symptom severity and gap-detection threshold.

An alternate technique often used is quantitative thermal sensory testing (QST). This technique assesses thermal sensation vs. vibration sensation. Shukla et al., (2005) used QST as a method to catch small fiber neuropathy at the early stages. All study participants presented with signs and symptoms suggestive of small fiber neuropathy but with normal or minimally abnormal NCT results were compared to a control group. Nerve conduction testing was conducted for F-wave, motor conduction on the median, ulnar, common peroneal, and posterior tibial nerves and for sensory conduction on the median, ulnar, and sural nerves. Sympathetic skin response (SSR) was tested for all participants. QST was tested using the limit method previously described to detect warm and cold sensation. Surface electrodes were used to test the upper limb on the hypothenar eminence and the lower limb at the dorsolateral border of the foot. The F-wave, motor conduction, and SSR were largely normal for all participants except for two participants whose SSRs could not be elicited. Mean cold sensation threshold was significantly lower for the symptomatic participants at both the hand and foot test sites. The mean warmth perception threshold was significantly higher in the symptomatic participants at the hand test site and at the foot test site. The authors concluded that QST was sensitive enough to detect small fiber neuropathy in the early stages in patients with otherwise normal NCT.

Another study measured NCT, QST, and skin biopsy and related nerve fiber density to measures of nerve motor and sensory function. The study participants showed evidence of small

diameter nerve fiber dysfunction. QST measurements and skin biopsy were conducted on the same leg approximately 5 cm above the lateral malleolus where the superficial peroneal nerve innervates. The QST was performed first, and two 3mm biopsies were taken from the same spot. The QST was performed by the same radiologist with the ambient air temperature set at 23° C skin temperature was set at 30° C. A 50 x 25 mm thermode was held to the skin for the entirety of the test. The temperature of the thermode was progressively decreased by 1° C/s until the participant perceived a feeling of cold. The temperature was then increased at the same rate until the participant indicated a feeling of warmth. This process was repeated ten times. The minimum temperature was 5° C and the maximum was 50° C. The means for each, perceived warmth threshold (WPT) and perceived cold threshold (CPT) were recorded as well as the difference between the two (limen). NCT was recorded using surface electrodes. Testing occurred in one symptomatic leg and at least one other limb. Two motor nerves and the sural nerve and, in some, the peroneal nerve were tested in the leg. Two motor nerves and three sensory nerves were tested in the upper limb. Parameters tested included conduction velocity (CV), peak latency, peak-peak amplitude, negative amplitude, proximal/distal amplitude decay, distal latency, and F-wave latency. NCT was conducted on the same leg as the other testing for 70 of the patients. The other five participants were tested on the opposite leg, but reported bilateral symptoms. The participants were grouped as either normal, as compared with age-matched reference material, or abnormal based on the NCT results. Thirty-eight of the participants were classified as normal and the remaining 37 were abnormal. These groups were compared to control group values from a previous study conducted by these authors.

The normal group had significantly lower fiber density than the control group. The normal NCT group had significantly higher fiber density than the abnormal NCT group. There was a significant difference between groups for WPT and CPT with the abnormal group showing larger thresholds for both. These two groups also differed significantly on limen with the abnormal group showing a significantly larger difference between WPT and CPT. Sural nerve amplitude was significantly different between groups for fiber density, limen, and CPT. There was a strong correlation between sural nerve amplitude and peroneal nerve amplitude. There were significant correlations between fiber density and limen and CPT for the abnormal group (Loseth et al., 2006).

A different study used NCT in participants with fibromyalgia and compared the results to those of a control group. The NCT was tested on the median (abductor pollicis brevis), ulnar (abductor digiti minimi), peroneal (extensor digitorum brevis), and tibial (abductor hallucis) nerves. Testing was conducted on the side with the most pronounced symptoms in the fibromyalgia group, and the dominant side in the control group. The measurements taken were compound muscle action potential (CMAP), distal motor latency (DL), motor conduction velocity ( $V_{mot}$ ), and F-wave latency. The sural nerve was tested for sensory velocity ( $V_{sen}$ ), and mixed velocity ( $V_{mixed}$ ). Peak amplitudes were also calculated for all nerves. There was a significant difference between groups on peroneal nerve  $V_{mot}$ . There was also a significant difference between groups on peroneal nerve DL (Ersoz, 2003).

Dyck et al. (2001) conducted a comprehensive NCT study on 430 healthy volunteers in order to establish normative values for future comparisons. Participants were 15 males and 15 females from each hemidecade in the range of 18 to 14 years. The researchers used age, gender,



height, and weight to calculate percentiles as well as a value which they called a normal deviate (ND). They proposed that percentiles and NDs be used for future comparisons for four reasons:

- 1) Percentiles provide a graded level of abnormality.
- 2) Percentiles allow the researcher to specify a level of normality which is most appropriate to the specific design of the study.
- 3) Percentiles provide useful information about dysfunction and/or disease even when values fall within normal ranges.
- 4) The use of NDs and percentiles allows direct comparisons among attributes, nerve conduction, and other such tests allowing the development of composite scores. (Dyck et al., 2001)

One of the major drawbacks of any type of nerve function testing is the sensitivity to external stimuli such as noise and temperature variations. One study quantified the effect of temperature on nerve conduction. All study participants had carpal tunnel syndrome affecting the median nerve but normal ulnar nerve conduction. Each participant's arm was cooled with ice-water prior to the start of testing. Test temperature ranged from 23.5° to 35° C. The ulnar and median nerves' sensory and motor conduction velocities were tested several times while the arm temperature elevated. The normal ulnar nerve was used as a control for the affected median nerve of the same arm. The researchers found that in all tests, except median nerve motor amplitude, distal motor latency, duration, area and amplitude all decreased as temperature increased. The ulnar sensory conduction velocity and area were affected by the cold more than

the median nerve with the velocity measure being significantly more affected. The median motor pathway was more effected by the cold than the ulnar nerve with distal latency, duration, and area all being significantly different (Ashworth et al., 1998).

Clark et al. (2007) evaluated the test-retest reliability of a variety of tests used to assess neuromuscular function. Seventeen participants (12 female, 5 male) underwent testing on two separate occasions approximately four weeks apart. The testing occurred at the same time of day for each participant. Participants were asked not to engage in vigorous physical activity within 24 hrs of the test sessions and not to drink caffeine the day of testing. The tests conducted included surface EMG of the soleus, medial gastroc (MG), lateral gastroc (LG), and the tibialis anterior (TA), tibial nerve stimulation, maximal contraction of the plantarflexors, and magnetic resonance imaging of the lower leg. The variables assessed from these tests were maximal strength (MVC), root-mean-squared (RMS) EMG, peak EMG, muscle cross-sectional area, peak net force from evoked stimulation, rate of evoked force, voluntary muscle activation, H-reflex excitability, specific force, reflex latency, M-wave latency, rate of force development, isometric steadiness, and time to task failure. Intraclass correlations as well as coefficient of variation were used to establish test-retest reliability for all of the previously listed variables. All intraclass correlation coefficients were greater than or equal to 0.70 with the exception of MG RMS, LG RMS, coactivity ratio, and time to task failure. All variable coefficients of variation were less than 20% (Clark et al., 2007).

### **Hoffmann Reflex**

The Hoffmann reflex is one measure of nerve function which has been determined to be reliable and valid. A review article by Palmieri, Ingersoll, and Hoffmann (2004) provided an

excellent description of the Hoffmann reflex (H-reflex) and how it presents itself on an EMG.

The H-reflex was discovered by Paul Hoffmann in 1910. The H-reflex is the electrically stimulated equivalent of the stretch reflex and is an assessment of alpha motoneuron excitability. Stimulation of a peripheral nerve causes an impulse to travel up the Ia afferent fibers through the spinal cord to synapse with the alpha motoneurons and continue to travel down the efferent fibers ultimately resulting in a muscle twitch of the corresponding muscle. This twitch will be visible on EMG. In addition to the H-reflex, the stimulus will also cause an impulse to travel directly down the efferent fibers to muscle and cause a trace on the EMG known as the M-wave. The H-reflex is smaller than the M-wave and presents on the EMG after the M-wave since the impulse has further to travel. The H-reflex will continue to increase with stimulus intensity until it peaks and then will begin to decrease. The decrease in the H-reflex after it peaks is due to the antidromic effect. The antidromic effect refers to the antidromic volley or electric impulse that travels the wrong way along the efferent pathway and interacts with the orthodromic volley traveling the right way down the efferent pathway. When the volleys collide, the largest volley will be decreased in amplitude but will continue the direction it was going. As the M-wave increases, it sends progressively larger antidromic volleys up the efferent pathway. These volleys impact the H-reflex volleys and cause them to decrease in amplitude. When the M-wave increases past the H-reflex amplitude, the H-reflex is cancelled out entirely and will disappear on the EMG trace. The M-wave will continue to increase with stimulus intensity increase until it plateaus.

Particular care must be taken when using the H-reflex as a variable as it is particularly sensitive to variations in body position, time of day, and external stimulation. The reflex is most

easily recorded in the lower limb in adults, but can be successfully recorded in the upper body, typically in the flexor carpi radialis. Inglis et al. (2007) provided an excellent review of the methodology used to elicit a sub-maximal H-reflex for the flexor carpi radialis (FCR). A monopolar silver/silver-chloride (Ag/AgCl) electrode was placed directly over the motor point of the FCR, an Ag/AgCl reference electrode was placed over the radial styloid and a ground electrode was placed over the medial epicondyle of the humerus. An anode and cathode were placed over the median nerve above the cubital fossa with an interelectrode distance of two cm. The stimulus was delivered in a square-wave pulse of 1 ms. The stimulus protocol involved a series of stimuli beginning sub-threshold and continuing with an increase of 1.2 millivolt (mV) until the  $M_{\max}$  was registered 10 times. The average of these ten stimuli was then calculated and a stimulus of 5% of this was determined. The 5% of  $M_{\max}$  intensity was then used to elicit the H-reflex for the remainder of the testing. Using a stimulation intensity of 5% of the  $M_{\max}$  allows the investigator to determine fluctuations in amplitude which might result from interventions performed. Stimulation at the  $M_{\max}$  level would block the H-reflex entirely, and stimulation at H-reflex maximum would similarly not allow for any increase in amplitude to be shown as a result of an intervention.

The H-reflex has emerged as a reliable and consistent technique in diagnosing nerve related issues including carpal tunnel, sciatica, and radiculopathy. Jaberzadeh and Scutter (2006) compared the H-reflex and M response in participants with diagnosed carpal tunnel syndrome (CTS) to an age matched control group of healthy participants. The results showed that the H-reflex amplitude was significantly higher in the CTS participants, the H-reflex latency was significantly longer, and the  $H_{\max}/M_{\max}$  was significantly larger. The authors concluded that the

increase in H-reflex amplitude could be related to increased sensitivity of the nociceptive afferent neurons and the wide dynamic range spinal neurons. This could cause a decreased threshold of the sensory and motor neuron thresholds allowing for increased excitability of the FCR motoneurons in the spinal cord. Similarly, the increase in  $H_{\max}/M_{\max}$  could be linked to greater excitability of the FCR motoneurons in the spinal cord. The increase in H-reflex latency could be related to a central delay in processing the signal or it could be an indicator of multiple lesions compressing the median nerve.

Similarly, Albeck et al. (2000) tested the sensitivity of electrophysiological testing for sciatica. All participants had suspected disc herniation at the L5 or S1 level, and exhibited symptoms of monoradicular sciatica. Comparisons were made within the group between those with confirmed herniation and those without. Nerve conduction testing (sensory and motor) was performed. The H-reflex (soleus) was evaluated in eight participants suspected of having S1 radiculopathy. The results of the tests were combined to determine the expected regret (ER) or the cost (human or economical) of making an incorrect decision. The H-reflex was found to be highly predictive of herniation, but was only tested in eight participants. There was not a significant difference in ER in the pre-surgical electrophysiological testing and the post-surgical electrophysiological testing. The authors determined that electrophysiological testing is not a reliable method by itself for determining disc herniation in participants with sciatica.

As effective as it is as an assessment tool, the H-reflex is highly variation. Thompson and Belanger (2002) examined the effect of intermittent vibration on H-reflex. Participants were tested before and after inline skating on a variable surface for 30 min. The variables measured included H-reflex (10% of  $M_{\max}$ ) and M response of the tibial nerve at the soleus muscle,

proprioception of the ankle joint, and MVC for the plantar flexors. As a control, the participants were also tested on a different day where they lay in the prone position with the skates on for 30 min. The vibrations measured at the skate level were  $141.8 \pm 25.2$  Hz and  $\leq 5$  g. The transmitted vibration at the tibia level was  $34.4 \pm 27.7$  Hz and  $\leq 2$  g. There was a significant 35% decrease in H-reflex amplitude after skating for thirty minutes. The decrease lasted as long as 35 min after skating stopped. There were no significant effects of wearing the skates in the prone position for 30 min on the H-reflex. The authors concluded that intermittent vibration could have a significant effect on nerve conduction in the lower limb. They concluded that the effect on H-reflex was likely due to a decrease in Ia afferent transmission

Another study examined the effect of time of day on the H-reflex and M response of the soleus muscle. H-reflex, M response, and  $H_{\max}/M_{\max}$  were examined in the morning and evening. The  $H_{\max}$  peak amplitude decreased significantly in the evening. The fast-twitch motor units contributed significantly less to the peak twitch amplitude of the  $H_{\max}$  in the evening. The authors concluded that the decrease in peak  $H_{\max}$  and fast-twitch motor unit contribution in the evening could be related to either a decreased input of the antidromic volley in the evening or general fatigue from the course of the day (Guette et al., 2005).

Agostinucci et al. (2006) examined the effect of circumferential pressure around the forearm on H-reflex in the FCR. The researchers found mixed results from the pressure application. Half of the participants showed facilitation, while the other half showed inhibition of the reflex. The facilitated H-reflex amplitude was significantly higher than the baseline value. The inhibited H-reflex amplitude was significantly lower than the baseline value. The H-reflex amplitude measurements after pressure was released were significantly higher than baseline, and

lower than the facilitated pressure measurements but not significantly so. The authors believe that the difference in H-reflex amplitude response to pressure could be related to individual differences in muscle fiber type concentrations in the FCR. Those with facilitated H-reflex amplitudes were believed to have a higher concentration of fast-twitch muscle fibers whereas those with inhibited H-reflex amplitudes had a higher concentration of slow-twitch fibers. The fast-twitch fibers were associated with large motoneurons which are more excitable than the smaller motoneurons of the slow-twitch muscles. Another explanation offered by the authors was that the Golgi Tendon Organ reflex pathway was affected by the change in pressure. The effect of the pressure again depended on the type of muscle fiber. The increase in H-reflex amplitude above baseline following pressure release was attributed to the cooling effect of air circulation in the absence of the pressure cuff. The explanation for the less significant difference in the facilitated group after pressure was released was that the reflex arc was already facilitated and thus would have less of a reaction compared to the inhibited group.

The H-reflex is particularly sensitive to body positioning, particularly the position of the arm and wrist. One study examined the effect of static shoulder position on H-reflex, among other measures, in two hand muscles. Participants were tested in a seated position with the right arm fixed and the shoulder abducted at 90° and the elbow bent at 90°. The forearm was pronated and the wrist was in neutral. The arm was statically placed either abducted 30° or adducted 30° during the test procedure. The H-reflex was tested in the abductor digiti minimi (ADM) and the first dorsal interosseous (FDI) muscles via ulnar nerve stimulation. There was a significant decrease in the H-reflex for the ADM in 30° abduction. The authors concluded that the

corticospinal pathway was less accessible for the ADM when in the 30° abducted position when compared to the FDI. The FDI was not affected by shoulder position (Dominici et al., 2005).

A related study analyzed the effect of wrist position and different levels of MVC on H-reflex of the FCR. The forearm was in neutral position and the wrist position was fixed for different trials at 100°, 165°, and 250°. The FCR H-reflex was elicited at each of these wrist joint angles while the participant sustained an MVC of 0, 10, 20, or 30%. The results showed that the wrist flexor EMG was significantly larger when the wrist was in the extended (100°) position. There were significant main effects for both wrist position and contraction level on H-reflex. H-reflex was increased when the wrist was flexed and decreased when the wrist was extended when compared to neutral. The H-reflex amplitude increased with level of contraction when in the neutral and extended positions. However, when in the flexed position, the H-reflex amplitude increased at 10% MVC from resting, but then decreased slightly at 20 and 30% MVC while still being elevated from the resting amplitude. The authors believed that the increased H-reflex amplitude in the flexed position might be related to a compensation by the neuromuscular system due to the disadvantage of contracting with the muscle in a shortened state (Chen et al., 2006).

When testing conditions and procedures are controlled, the H-reflex is known to have good reliability. Inglis et al. (2007) sought to provide reliability data in provoking the H-reflex in the flexor carpi radialis as well as determine the number of practice sessions necessary to be considered qualified to consistently and accurately elicit the H-reflex for this muscle. One experienced practitioner was compared to an inexperienced practitioner. Each practitioner tested the same participants and measured M-wave maximum ( $M_{max}$ ), the amplitude of the H-reflex at



5% of  $M_{\max}$  ( $H_{5\%}$ ), and the H-reflex latency. The results showed a correlation of  $r = 0.84$  for the  $M_{\max}$  and an  $r = 0.70$  for  $H_{5\%}$ . The correlation for H-reflex latency was significantly lower at  $r = 0.38$ . An ANOVA was used to determine the difference between the first half testing sessions to the second half testing sessions. The result showed a significant increase from and  $r = 0.22$  to an  $r = 0.72$  which indicates a learning effect on the inexperienced practitioner's behalf.

An earlier article by the same group of authors and using the same test procedure sought to determine both the reliability of the variables measured, but also the ease of eliciting the H-reflex without a facilitating isometric contraction. A total of 39 participants (20 males, 19 females; age not reported) each completed four days of testing with at least 24 hrs between test sessions. The participants were positioned supine with the right arm abducted  $45^\circ$ . The variables measured included  $H_{5\%}$ ,  $M_{\max}$ , and H-reflex latency. The H-reflex was elicited without facilitation in 37 of the 39 participants tested. The ICC for the variables were excellent for  $M_{\max}$  ( $r = 0.97$ ) and  $H_{5\%}$  ( $r = 0.92$ ) and good for H-reflex latency ( $r = 0.89$ ) (Christie et al., 2005).

A similar article endeavored to test the between days reliability of testing the FCR. The variables measured were the  $H_{\max}$ ,  $M_{\max}$ , H-reflex latency, and the  $H_{\max}/M_{\max}$  ratio. Participants were tested on two occasions at the same time of day with at least 72 hrs between test days. All participants were right hand dominant and the right arm was used for testing. Additional anthropomorphic measurements included arm length, height, and weight. The electrode placement was similar to that of previously discussed articles. The participants were seated in an upright chair with the right arm fixed at an angle of  $135^\circ$  and the forearm resting horizontally and supinated on a table. The participants held a 1kg weight throughout the testing procedure in an effort to provide a background contraction of the FCR to better elicit the H-reflex. The

stimulation protocol involved stimulus impulses of 0.8 ms square-wave pulses, at a frequency of 0.5 Hz, beginning sub-threshold for the H-reflex (0.5 milliamperes (mA)) to supra-threshold for the M response increasing at increments of 0.3 mA. There were no significant differences between days for any of the measured variables. The intraclass correlations ranged from  $r = 0.66$  for the  $H_{\max}/M_{\max}$  ratio to  $r = 0.89$  for the M response latency. The  $H_{\max}$  amplitude showed an  $r = 0.68$  with a corresponding power of 86%. The authors found that there was good between-days reliability for all variables measured (Jaberzadeh et al., 2004).

Between subjects, between days, and between conditions variability of the soleus H-reflex and M response were assessed by Brinkworth et al. (2007). The authors used a Gaussian function to model the H-reflex and a hyperbolic function to model the M response. The authors also used curve fitting to examine the variability under the different conditions. The stimulation protocol involved testing the participants ( $n = 3$ ) in a seated position with the knee fixed at  $120^\circ$  and the ankle fixed at  $100^\circ$ . The head and arms were supported. The participants were tested both with the soleus relaxed and at a 50% MVC. The stimulation protocol involved stimulating the tibial nerve over a range of intensities beginning at two mA below that necessary to elicit an H-reflex with the muscle relaxed and at 50% MVC to three mA above that necessary to elicit a maximal M response with the muscle relaxed. A total of 15 intensities were used and were equally separated except for one being placed between the upper two intensities. A total of ten blocks of the intensities were administered. During the muscle contraction condition, the first stimulus was given immediately after the appropriate MVC was reached. There was a minimum of two min between each condition. The H-reflex was normalized both for size and location on the M response curve. The results showed variability at all intensity levels, but the largest

variability was at the middle intensities which elicited both an H-reflex and an M response. The responses to the stimuli when there was a background contraction were not significantly different from other responses that same day. However, the same day responses elicited at rest were significantly different from each other. However, when the study was replicated on a different day, all of the responses varied greatly. The authors advocate using an entire stimulus intensity curve to control for variability and to elicit at least five stimuli at each intensity to best measure changes in amplitude between conditions. They also recommend normalizing the stimulus intensity to the M response curve to fully realize any changes in the H-reflex.

It is known that the H-reflex is susceptible to external stimuli, but it is also susceptible to variation due to pain. Le Pera et al. (2001) studied the effect of localized pain on the H-reflex and motor-evoked potentials (MEPs). Tonic pain was produced by injecting 5% hypotonic saline solution into the abductor digiti minimi or FCR. The experiments varied by location of injection and measurement i.e. measurement on contralateral vs. ipsilateral side, and whether the solution was injected subcutaneously or directly into the muscle. Each experiment also had a control run in which a non-painful 0.9% isotonic solution was injected. Pain was measured throughout the experiment using a VAS. With injection into the FCR, there was a significant reduction in MEP during peak pain and during recovery. The H-reflex was significantly reduced during the recovery stage, approximately one min after peak pain, but not during peak pain. The authors believe these results indicate a motor cortex inhibition in response to pain which is followed by reduced excitability in both the cortical and spinal motoneurons (Le Pera et al., 2001).

The H-reflex has shown to be sensitive to spinal loading and unloading. Variations in the reflex in some cases are believed to be due to an excitatory response of the central nervous system resulting from activation of surrounding musculature, but mechanical nerve root compression may also be a significant contributor to variations in the reflex amplitude. The effects of cervical traction on the FCR H-reflex amplitude and M wave response were studied by Hiraoka and Nagata (1998). Participants ( $n = 10$  males) lay supine while cervical traction was applied. The H-reflex (50%) and M wave were tested at zero, three, six, and nine kilogram-force (kgf) of traction. Each trial lasted four minutes, with the variables being tested in 12 waves per minute. The traction was applied during the second minute of each trial. The 12 waves were averaged for each minute and a percentage of control (POC) was determined. The POC was the average of the H-reflex amplitude divided by the first minute's amplitude multiplied by a hundred. The results showed that traction increased the H-reflex amplitude in all cases. This effect was significant at the level of 3 kgf. The authors concluded that there might be a facilitatory effect of the flexor reflex afferent system on the FCR H-reflex.

Many believe that mechanical compression of the nerve root over time may be a contributing factor to pain and other symptoms of neuropathy. Alrowayeh and Sabbahi (2010) used the H-reflex to determine the degree of neural compromise in participants with non-specific low back pain (NSLBP). Participants were tested while lying prone and while standing. Soleus H-reflex amplitude and latency were tested bilaterally and the side-to-side (H/H) ratio was used as an indicator of neural compromise. A ratio below .5 indicates an abnormality. When lying prone, 5 of the 30 participants showed H/H ratios below .5 indicating some degree of compromise. When standing, 6 of the 30 showed H/H ratios below .5. There was no significant

difference in latency between those who showed decreased H/H ratios and those who didn't. The researchers believe that the decrease in the H/H ratio was likely due to a conduction block and decreased recruitment of spinal motoneurons, and not actual nerve root lesions since there was not a corresponding change in latency.

Ali and Sabbahi (2000) examined alterations of the H-reflex amplitude and latency of the soleus during prone lying, standing, standing while holding a 20% bodyweight load, and while standing unloaded by 25% via a ZUNI II unloading system. The results of the study indicated that H-reflex amplitude was inhibited in the standing, loading, and unloading conditions compared to the prone lying condition. This is likely due to the increased load on the spine and the nerve roots. The loading condition was the higher than either standing or standing unloaded indicating that additional muscle activation may have initiated a slight excitatory response.

Al Rowayeh et al. (2010) examined the effect of forearm position and spinal loading on the H-reflex in the flexor carpi radialis in healthy adults. Participants were tested with the forearm both pronated and supinated while lying supine, sitting, and sitting while wearing a 4.5 kg helmet. Four stimuli were recorded for each condition and the condition order was randomized. The results indicated that there was a significant interaction effect between forearm position and loading condition. Simple effects showed no significant differences between the loading conditions with the forearm in supination, however, there were significant differences in the H-reflex amplitude with the arm in pronation. H-reflex amplitude increased significantly from lying supine to sitting and sitting with load. There was not a significant difference between sitting and sitting with load. Forearm pronation showed significantly greater H-reflex amplitudes in all three loading conditions. H-reflex latency was unaffected by body or forearm

position. The researchers believe the increase in H-reflex amplitude from lying supine to sitting and sitting with load was due to facilitation from increased muscle activation of the cervical and core musculature. This would increase the cervical spinal motoneuron excitability. They believe that pronation likely also facilitated the reflex because of this increased excitability.

Sabbahi and Abdulwahab (1999) examined the effect of postural changes on the H-reflex in the FCR in healthy adults. There were twenty-two participants (14 male, 8 female; age  $39 \pm 9$  years). All participants were seated upright with the right arm resting in the lap in a slightly flexed position. The H-reflex was tested by placing a stimulating electrode over the motor point for the FCR and the recording electrode was placed 2 cm lateral to the stimulating one. The stimulus occurred in .5 ms pulses at a frequency of .2 pulses per second at the H-maximum intensity. The average of four successful recordings was used for data analysis. The H-reflex amplitude and latency were both recorded. The positions tested were neutral, left/right rotation, left/right lateral flexion, protraction, retraction, flexion, and extension. Each position was held steady for 30 sec. The results showed a significant increase in H-reflex amplitude in all head positions except flexion when compared to neutral ( $p < 0.001$ ). Flexion caused a decrease in H-reflex amplitude compared to neutral. The authors believed the increases in amplitude were related to a mechanical decompression of the nerve root or an opening of the space occupied by the nerve root. The decrease in amplitude with flexion was believed to be due to an increased compression of the nerve root by the musculoskeletal tissue surrounding it. H-reflex latency did not show any significant changes with any of the head positions. The authors also believed that the modulation of amplitude was due solely to the mechanical decompression/compression of the nerve root because the positions were held statically eliminating any vestibular effects, and the

$H_{\max}/M_{\max}$  values changed concurrently with the amplitude values indicating that muscular changes were not the cause for modulation.

## **Conclusion**

Studies have established that aviators are suffering from radiating, radicular, and localized pain, neuralgia, neuritis and even paralysis in the neck, shoulders, back, and arms. Imaging studies have shown that there is evidence of degeneration of the intervertebral discs as well as the vertebrae. There is a link between HSM and increased risk of injury, and there have been studies which have shown that high levels of loading can cause spinal degeneration. There are many methods of testing nerve function. The H-reflex has been found to be a reliable and valid measure of nerve function in superficial nerves. Despite the implication of nerve involvement in the injuries described, nerve conduction testing has yet to be used to determine either the acute or the long-term effect of HSM on nerve function.

## CHAPTER THREE

### Methods

#### Participants

**Recruitment.** The participants for this study were adult civilians recruited from the University of Arkansas. The participant sample for this study excluded those otherwise eligible who reported pre-existing neck or nerve root issues related to HSM. In order to establish the H-reflex as a valid measure of nerve compression related to chronic HSM use, it is first important to determine if the H-reflex is affected by HSM or head position in a healthy population, effectively controlling for any preexisting conditions which might affect the results.

Participants were recruited through the University of Arkansas via email, posters placed on bulletin boards in common areas of campus, classroom briefing sessions, and through word of mouth. At the individual professors' discretion, extra credit was offered for participation. No other compensation was offered to the participants.

**Sample size.** There was a sample size of 14 for this study. The overall predicted power for the study was of 0.59. This was calculated using an alpha level of .05, and effect sizes ranging from negligible ( $d = 0.08$ , Al Rowayeh et al., 2010) to medium and large ( $d = .42$  to  $d = 1.33$ , respectively; Sabbahi & Abdulwahab, 1999) from a similar studies which measured H-reflex amplitude and latency of the flexor carpi radialis muscle. Most related studies used sample sizes from 10 to 20 (Alrowayeh, et al., 2005; Boroojerdi, Battaglia, Muellbacher, & Cohen, 2000; Dominici et al., 2005; Jaberzadeh, et al., 2004; Funase & Miles, 1999; Lagerquist, Zehr, Baldwin). Twenty-three participants were consented and data collection was completed for 14.



**Inclusion/exclusion criteria.** No exclusions were made based on gender.

Inclusion criteria:

- deemed “healthy” at the discretion of the study physician and Associate Investigator based on information self-reported in a medical history questionnaire.
- range in age from 19-40 years
- discernible H-reflex found during baseline testing

Exclusion criteria:

- current active duty military status
- current reserve/national guard status or prior military service in a combat or combat support military occupational specialty (MOS)
- current reserve/national guard status or prior military service with history of deployment to combat theatre regardless of MOS
- pregnancy in the third trimester
- personal history of nerve injury
- nerve degeneration
- neck injury
- upper body muscle weakness
- numbness or tingling in the arms
- vertebral fracture
- current neck pain
- degenerative disorder of vertebrae or intervertebral disc
- family history of nerve degeneration

- consistent use of HSM within the last year
  - motorcycle helmet
  - hard hat
  - sports helmet
  - military helmet (ACH, flight helmet, etc.)

**Informed consent.** Once interested volunteers contacted the study personnel from USAARL and expressed their interest in participating, they were provided a copy of the consent form and the medical history questionnaire to review and complete prior to the consent session/baseline testing. After all questions were answered to the satisfaction of the volunteer and the volunteer agreed to participate, the informed consent document was signed and a copy was given to the volunteer. Following the informed consent procedure, volunteers were assigned a participant identification number which was reported on all data collection sheets.

**Participant identification.** All participants were assigned an identification number upon signing the informed consent document. This number was the only means of identifying the participant throughout the entirety of the study. Any paper or electronic files generated during the course of the study used the identification number as the root of the file name.

The informed consent document was the only record kept with both the participant name and the identification number on it. These documents are kept in a locked cabinet in the principle researcher's office. The principle and associate researchers are the only individuals with access to these documents.

## **Variables**

The two primary dependent variables for this study were H-reflex amplitude and H-reflex latency. The two independent variables are HSM condition (three levels) and HP (five levels). Neck Rating Scale (NRS-11) scores were analyzed for trends relative to the HSM conditions for use as guidelines for participant recruitment for future studies. Range of motion measurements were compared to determine the effect of the helmet on available range of motion.

## **Equipment**

A modified HGU-56/P and an adjustable headband were used for data collection (Figure 1). This protocol required participants to hold static postures at the maximum position attainable during AROM positioning of the head wearing three different HSM conditions: negligible HSM (N\_HSM), a low weight-moment configuration (1\_HSM), and a high weight-moment configuration (2\_HSM). The low weight-moment configuration was representative of the standard flight helmet worn without night vision goggles (NVGs), counterweight, or power supply. It had a mass of 1.5 kg and a center of gravity (CG) offset of 1.0 cm with a total weight-moment of 15 N-cm. This represented a helmet that would be worn during a typical day flight under good visibility conditions. The high mass configuration for this study was determined in an effort to resolve an issue from the previous research (Fraser, Alem, & Chancey, 2006), but still maintain a configuration likely to produce effects while remaining within the allowable standard established in the USAARL curves. The researchers found that the high mass/high CG offset configuration continually slipped forward on the participant's head during testing. This resulted in participant discomfort and also caused the participants to continually readjust the helmet to the starting position. The researchers determined that this movement was likely due to

the high mass (3 kg) at such a significant CG offset (5.4 cm). This continual movement of the helmet on the head altered the location of the InertiaCube™ across trials which could potentially skew the data. In order to address this issue, a counterweight (12 oz) was added to the rear of the helmet (1 cm posterior offset). This adjustment increased the overall mass of the configuration, and shortened the CG offset leaving an overall weight-moment of 155 N-cm versus the 159 N-cm from the previous study. This configuration was within the limits of similar testing conducted at the USAARL (Fraser, Alem, & Chancey, 2006) which was based on the “USAARL Curves for Head-Supported Mass Limits” established by Barazanji and Alem (2000) (Figure 2). For the N\_HSM condition, participants wore an adjustable harness from an SPH-4 flight helmet with a metal rim attached (0.35 kg) allowing the InertiaCube™ to be mounted in the same relative position (geometrical center) as the other two conditions.



a.



b.

*Figure 1.* Modified HGU-56/P with added mass, and InertiaCube™ (a) and adjustable SPH-4 harness and metal rim for N\_HSM condition (b).

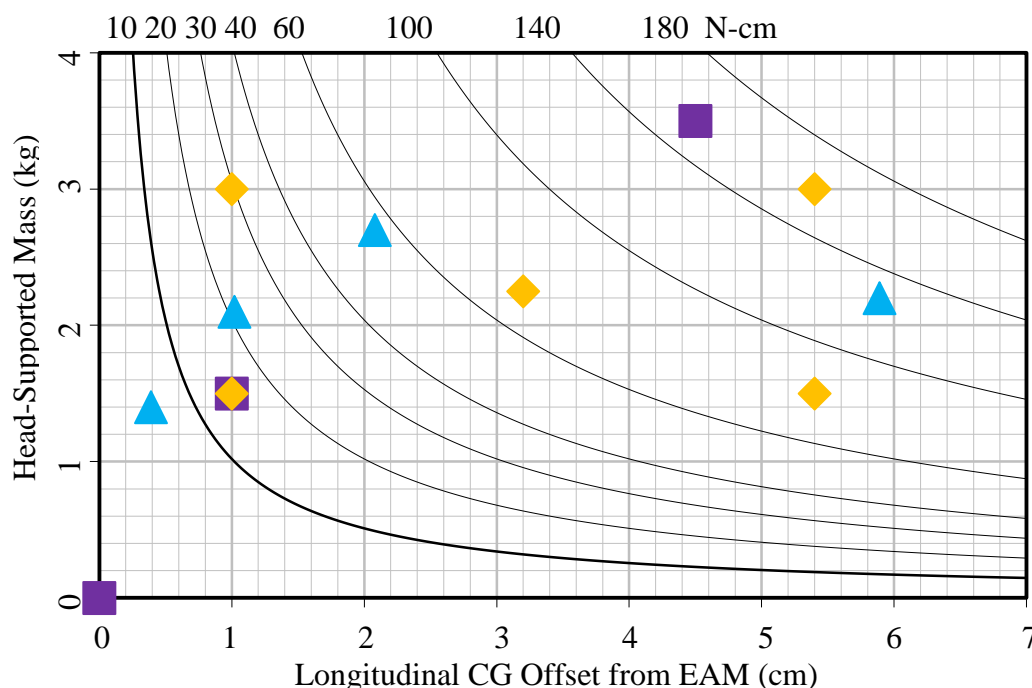


Figure 2. Graph of helmet configurations for the current study, the Fraser, Alem, & Chancey (2006) study, and current fielding.

Note.

1. Squares represent the experimental weight and longitudinal offset configurations used in this study:
 

(1) 0.35 kg x 0 cm (0 N-cm)	(2) 1.5 kg x 1.0 cm (15 N-cm)
(3) 3.5 kg x 4.5 cm (155 N-cm)	
2. Diamonds represent the experimental weight and longitudinal offset configurations used in the Fraser, Alem, & Chancey, (2006) study:
 

(1) 1.5 kg x 1.0 cm (15 N-cm)	(2) 3.0 kg x 1.0 cm (29 N-cm)
(3) 2.25 kg x 3.2 cm (71 N-cm)	(4) 1.5 kg x 5.4 cm (79 N-cm)
(5) 3.0 kg x 5.4 cm (159 N-cm)	
3. Triangles represent helmet configurations currently in use by Army aviators:
 

(1) HGU-56/P, unloaded, no goggles, no power, no counterweights	1.40 kg x 0.39 cm (5.4 N-cm)
(2) HGU-56/P, visor down with HDU and EOHSS	2.10 kg x 1.02 cm (21 N-cm)
(3) HGU-56/P, goggles in up position, 12 oz. counterweight	2.70 kg x 2.08 cm (55 N-cm)
(4) HGU-56/P, goggles, batteries, no counterweight	2.20 kg x 5.89 cm (127 N-cm)
4. The external auditory meatus (EAM) is a small fleshy part over the ear canal generally designated to represent the location of the head center of gravity in the sagittal plane. Weight-moments are expressed with respect to the EAM for consistency with previous studies.

The helmet and headband were positioned on a size appropriate Cadex headform (size J for Small, Medium helmets and headband; size M for Large helmet) according to AIHS-FS-0002. The front edge of the helmet shell/headband was positioned  $2^{1/8}$  in. above the Cadex headform Basic Plane (Figure 3a and b). A laser was used to line up the vertical center line of the headform with the center of the grommet mounted on the front of the helmet.



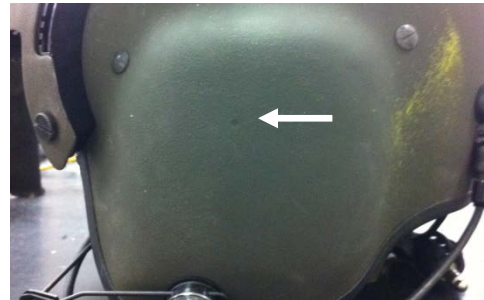
a.



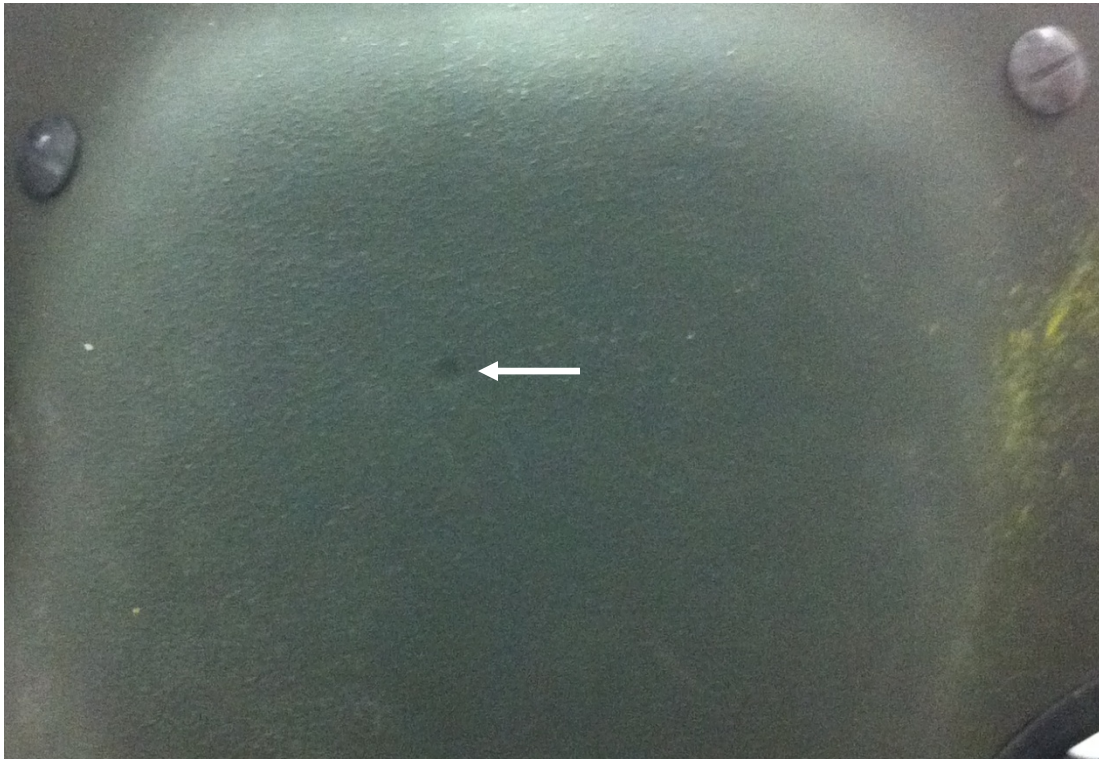
b.

*Figure 3. Alignment of Headband (a) and Helmet (b) on Cadex Headform (Size J) as worn according to standard AIHS-FS-0002.*

Lateral level was established by measuring the top edge of the grommet (Figures 4) placed in the manufacturing artifact dimple in each earcup (5 and 6). The helmet was adjusted until the left and right grommet heights were equal.

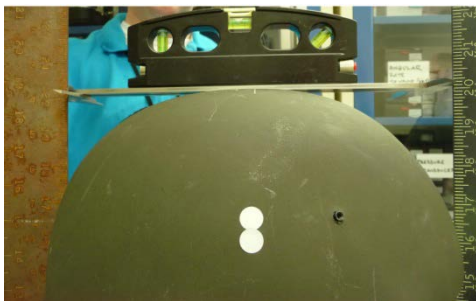


*Figures 4 and 5. Earcup grommets and manufacturer's dimple on earcup.*



*Figure 6.* Close-up of manufacturer dimple on earcup.

The center line in the sagittal plane was established by positioning carpenter squares at the back edge of the front grommets (Figure 7a). Calipers were used to measure the distance between the carpenter squares. This measurement was divided by two and the half-measure was taken from the right carpenter square (Figure 7b).



a.



b.

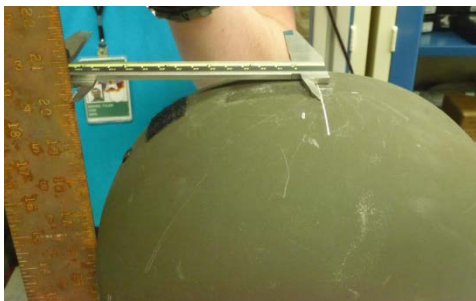
*Figures 7a and b.* Establishing center line of sagittal plane with carpenter squares and calipers.



The center line in the frontal plane was established using the same technique with the carpenter squares placed at the widest part of the front and back of the helmet (Figure 8). The half-measure was taken from the rear carpenter square (Figures 9a and 9b). The InertiaCube™ was centered over the intersection of the lines drawn in the frontal and sagittal planes with the screw holes positioned on the frontal plane line.



*Figure 8.* Carpenter square alignment for frontal plane measurement.



a.



b.

*Figure 9.* Establishing the center line of the frontal plane on a helmet (a) and the headband (b).

Individual InertiaCubes™ were mounted to each helmet and the headband. Once mounted, the helmets were repositioned on the Cadex headforms for a baseline zero reading. The baseline reading will serve to determine the consistency between helmet/headband mounts and give a baseline error for future measures when the helmet is worn by the participants.



The InertiaCube™ was used to determine the coordinates for the different head positions with respect to the participant's anatomical zero (neutral) while seated. Neutral was determined as the position where the participant's head is comfortably placed over the shoulders with the eyes looking straight ahead and the chin is level with the ground. The InertiaCube™ was on top of the helmet/headband and the zero was set. Head and neck motion data were collected using the InterSense software tracking system, with inertial 3-degree of freedom (dof). The InterSense InertiaCube™ is able to measure angular rate of rotation, gravity, and Earth's magnetic field on three perpendicular axes. The unit weighs 59.5 g and was affixed to the top of the experimental helmets or to the top of a head harness for the baseline session. The angular rates are integrated to obtain the orientation (in terms of yaw, pitch, and roll) of the sensor. The resolution of this device is  $0.02^\circ$  (RMS), with an update rate of up to 500 samples/sec. These coordinates were entered into the software program which was used to direct the participants to the head positions required for the respective condition. The InterSense InertiaCube™ coordinates were used to measure range of motion. In addition, the CROM™ cervical range of motion goniometers system was used to measure baseline range of motion for comparative purposes.

All H-reflex testing followed the standard operating procedure for the Grass Telefactor equipment which is kept on file at the USAARL. The H-reflex was evoked with a surface stimulus electrode placed proximal to the cubital fossa over the median nerve (Sabbahi & Abdulwahab, 1999) and a dispersive electrode placed on the back of the arm above the elbow. The stimulus and dispersive electrodes were connected in series with an isolation unit (Grass Telefactor SIU5, Astro-Med, Inc., West Warwick, RI) and a stimulator control unit (Grass Telefactor S88, Astro-Med Inc.) that delivers a single square-wave pulse for 1 ms. The

recording electrode (Delsys wireless active electrode) was placed over the belly of the FCR. The belly of the muscle was palpated and identified for electrode placement by having the participant flex and radially deviate the wrist while manual resistance is applied to the thenar eminence. The Delsys active electrodes have a built-in ground, so no additional ground electrode was required. The recording electrode had a pre-amplification of 5V. Raw data were collected and processed via custom developed software. Ten maximum M-waves were recorded at baseline. The M-wave is considered to be a measure of the percentage of the motoneuron pool being recruited through electrical stimulation. A maximum M-wave is indicative of all innervated muscle fibers being recruited. This is traditionally used as a method of normalization allowing for between participant comparisons (Palmieri *et al.*, 2004). H-reflex stimulation typically occurs at a percentage of M-wave maximum which allows researchers to say that all participants were tested with a stimulus equivalent to “X”% of that needed to recruit all muscle fibers innervated by the median nerve. For the purposes of this study, we recorded the H-reflex at a stimulation level of approximately 20% of M-wave maximum ( $H_{20\%}$ ). H-reflex latency varies between individuals and is related to height and arm length. These two factors were recorded for trend analysis.

## Procedures

The testing was conducted on four different days with at least 24 hrs between test days (Table 1).

Table 1

### *Study Schedule*

Day	Session	Activities
1	In-processing	Informed consent Medical history questionnaire Baseline H-reflex testing Anthropometry Helmet fitting
2	Testing	1 of 3 HSM configurations tested in each head position
3	Rest	
4	Testing	2 of 3 HSM configurations tested in head position
5	Rest	
6	Testing	3 of 3 HSM configurations tested in each head position

**Anthropometric measures.** Anthropometric measurements included stature (height), weight, left/right arm length, and cervical range of motion. Cervical range of motion (CROM) was measured using the Cervical Range of Motion Instrument (Performance Attainment Associates), a custom designed goniometry system for CROM measurements on all axes. All measurement standards were those used in a US Army anthropometric survey (Gordon, et al., 1989) and were recorded on the Anthropometric data collection sheet (appendix B).

### **Test preparation.**

1. The participant was asked to give a baseline rating for perceived neck pain using the neck rating scale (NRS-11). The NRS-11 uses 0 to represent no pain and 10 to represent the worst pain imaginable. Scores from 1 to 3 represented mild pain, 4 to 6 represented moderate pain, and 7 to 10 represented severe pain. (Fejer *et al.*, 2005) A researcher reviewed the NRS-11 with the participant to ensure full understanding of its use. If the baseline rating was not 0 then the participant was excused from further participation on that day.
2. The area where the electrodes was placed was prepared by cleaning the site with an alcohol pad and, if necessary, shaving any hair that interfered with the electrode-skin interface. The electrodes were affixed to the participant with tape.
3. A disposable pregelled stimulus electrode was placed over the median nerve just proximal to the cubital fossa, medial to the biceps tendon. A reusable pregelled dispersal electrode was placed on the dorsal aspect of the arm proximal to the elbow. The H-reflex recording electrode (Delsys) was placed over the belly of the participant's right FCR. The belly of the muscle was palpated and identified for electrode placement by having the participant flex and radially deviate the wrist while manual resistance was applied to the thenar eminence. Generally, the belly of the muscle lays approximately four finger-widths proximal to the medial epicondyle of the humerus in line with the midpoint of the cubital fossa. The muscle runs medial to lateral from the medial epicondyle of the humerus to the second metacarpal.

4. The participant conducted warm-up stretches in accordance with US Army Field Manual FM 21-20: Physical Fitness Training. The stretches were chosen to specifically target the neck musculature which was used to perform the movements in the test protocol. The specific stretches were:
  - (a) Head/Neck Rotation – The participant stood with his/her feet shoulder-width apart and arms relaxed at his/her side or with his/her hands placed on the hips. He/she slowly rolled the head in a clockwise direction making a complete circle. He/she repeated this movement three times clockwise and three times counterclockwise.
  - (b) Upper-back stretch – The participant stood with his/her feet shoulder-width apart. Arms were extended forward at shoulder height. With fingers interlaced and palms facing outward, he/she extended the arms and shoulders as far as possible. This position was held for 10 to 15 seconds (sec) and repeated three times.
  - (c) Neck-shoulder stretch – The participant stood with his/her feet shoulder width apart and arms behind the back. He/she grabbed the left wrist with the right hand and pulled down on the left arm with the right. He/she simultaneously laterally flexed the head to the right side. This position was held for 10 to 15 sec. The stretch was repeated three times on the right side and then three times on the left side. The right arm was pulled downward by the left and the head was laterally flexed to the left side. The stretch was held for 10 to 15 sec and repeated three times.
5. The participant was seated in the test chair with the feet flat on the floor so that the knees and ankles are set at 90°. The arms were relaxed at his/her sides with the forearms

resting on a pillow with the palms up. The participant was instructed to remain as still as possible throughout the testing and to breathe normally.

### **Baseline testing.**

1. The H-reflex maximum amplitude and latency values and M-wave maximum amplitude was established for the right arm. The protocol for establishing an H-reflex and finding M-wave maximum is based on Inglis *et al.*, (2007). First, a low level, sub-threshold, stimulus was used and increased in small increments. The effective stimulus varies with each individual. Stimuli started low (5 mA) and increased from there. For each stimulus, the researcher observed the corresponding muscle twitch on the computer. Once the H-reflex was found, the researcher continued to increase the stimulus intensity until the M-wave maximum was found. When further increases in intensity did not result in further increases in M-wave, the stimulus intensity was noted and 10 consecutive responses were recorded and averaged as the M-wave maximum amplitude ( $M_{max}$ ). During the study, H-reflex was recorded at a stimulus intensity needed to produce an H-reflex amplitude of approximately 20% of M-wave maximum ( $H_{20\%}$ ). Rate of stimulus application was approximately 1 every 5 sec. The latency value corresponding to this maximum amplitude was recorded. This process was repeated up to five times, as needed.
2. Baseline Euler angle coordinates were established for the neutral head position and for the maximum obtainable end range of active motion for neck flexion, extension, and left and right rotation. These Euler angle coordinates were used as the objective head position throughout the remainder of the testing. The following verbal descriptions were used to direct the participants into the proper head positions:

- a) Neutral – sit up straight with your head positioned over your shoulders, eyes looking straight ahead, and chin level with the ground,
  - b) Flexion – touch your chin to your chest,
  - c) Extension – look at the ceiling
  - d) Left rotation – look over your left shoulder,
  - e) Right rotation – look over your right shoulder.
3. The participants were informed that each of the previously held positions could be held for up to 1 min during each testing trial. If the participant became uncomfortable in any of these positions, indicated as a NRS-11 score of seven, the trial was ended.

**Condition testing (all HSM conditions).** The participants performed one HSM condition each day with a minimum of 24 hours between each session. Five head positions were tested for each of the conditions.

#### Testing Protocol (Approximately 45 min)

1. At the start of testing each day, a new M-wave maximum and  $H_{20\%}$  was established using the same procedures detailed above. This  $H_{20\%}$  stimulus intensity was used for the remainder of testing that day.
2. Following the baseline H-reflex testing, participants remained seated in the test chair, but donned one of the three HSM configurations. The participants sat for a 30 min exposure period. The first 25 min of the exposure period was divided into three equal sections. During each section of the exposure period, the participants were randomly guided into all test head positions except for neutral. The participant returned to neutral between each position. Auditory cues were given to direct the participant into the correct

positions. The InertiaCube™ on the crown of the HSM configuration tracked the participant's head location throughout the movement. The auditory cue was a beeping sound which was heard as the head approached the appropriate position. The beeping was slowest when the head was positioned near neutral. As the head moved to the correct position the beeping increased in cadence. When the head was positioned within the allowable window the beeping stopped. The participant held each head position for 30 sec. After 30 sec, the participant returned the head to a neutral position for 60 sec. Head position order was randomized for each section. Each head position was assumed once per section. At the end of the third section, the participant remained in the neutral position for an additional five minutes before the H-reflex testing began. This five minute period allowed the participant to rest and minimized any carry-over effects of movement and external stimuli on the H-reflex.

3. During the last minute of the five minute rest period, ten stimuli were given in the neutral position (loaded neutral). The participants were then instructed to move their heads into the four other head positions in random order (Sabbahi & Abdulwahab, 1999). Unlike the previous three sections, the participant did not return to neutral between each head position. For each condition the participant moved the head to the end range of motion position and held it there. The same auditory cue was used to assist the participant in assuming the correct head positions.
4. The participant held each head position for approximately 60 sec or until a reported score of 7 on the NRS-11.



5. While in each head position, H-reflex amplitude and latency were tested in the right arm every 5 sec. Neck muscle activity was also recorded. A total of ten stimuli were administered and the reflex recorded for each position.
6. In the event that the head moved out of the allowed window for position, the auditory cues were present to direct the participant back to the correct position.
7. During each section of the testing the participant verbally indicated perceived pain/discomfort at least once using the NRS-11.

**Post-test procedures.** Each participant was provided a handout detailing stretches to complete two to three times throughout the next day to alleviate any potential neck soreness which might be experienced. A 24-hour post-test email was sent asking the participant to report any adverse side effects.

### **Statistical Analysis**

This study used a split-plot design with participant as the whole-plot block, HSM condition as the whole-plot factor, and head position as the sub-plot factor. Separate univariate analyses were conducted for H-reflex amplitude and latency. Follow-up analyses were conducted by calculating effect sizes using least-square means. Each participant served as their own control. Testing sessions were separated by at least 24 hrs in order to minimize any carryover effects. The 10 H-reflex amplitude and latency values for each position at each condition were averaged for analysis. EMG MVC was analyzed separately from H-reflex amplitude and latency. EMG was analyzed as a possible correlate to H-reflex amplitude and latency. NRS-11 scores were analyzed for trends related to HSM condition. The SAS 9.1 statistical software package was used to analyze the results.

## CHAPTER FOUR

### Results

#### Introduction

This was a split plot design with the individual participant treated as a block. The main or whole plot was the HSM condition which was arranged in a randomized control block (RCB) design for each participant/block. The subplot was head position (HP) and was also arranged as RCB. HSM condition and HP were treated as fixed effects and participant was treated as a random effect. Test days were separated by a minimum of 24 hrs to minimize carry-over effects. Participants 7 and 15 had longer than 24 hrs between test days due to scheduling conflicts.

A two-way ANOVA was used to answer the research hypotheses. The first factor, HSM condition, had three levels and the second factor, HP, had five levels. The two dependent variables, H-reflex amplitude and latency were not significantly correlated ( $r = .13, .06$ ) and thus were analyzed separately. The first analysis assessed the effect of HSM and HP on the H-reflex amplitude relative to the initial baseline amplitude each day. The second analysis assessed the same factors effects on H-reflex latency. Effect sizes were used to assess the individual hypotheses. Effect sizes were calculated using the Least Squares means and the standard error. Baseline descriptive statistics for all participants are presented in Table 2.

All treatment combinations were tested for each participant. Ten stimuli were given for each HP and averaged for analysis. The amplitude was calculated as the difference from peak to peak of the waveform. The latency was calculated using an algorithm which found the first point to exceed 8% of the absolute value of the maximum slope for the data segment. Sometimes the amplitude was so low that the algorithm returned a zero value for the latency. This is a false

value because the latency would be consistent with previous traces had the amplitude been of a magnitude for the algorithm to calculate it. When a zero value was given for the latency, the average latency for the ten traces was used for that value. If all ten traces had amplitude's low enough that the algorithm could not calculate the latency then the average latency for that test day was used.

The data from all participants were graphed individually and checked for outliers. The data met the minimum model assumptions for a two-way ANOVA. Due to equipment and software malfunction, not all stimuli were recorded for each participant in each position. When 10 stimuli were not available for averaging, all available stimuli were used. There was significant software failure for participant 11 on the 1\_HSM condition test day resulting in only one head position being recorded. In addition, the results from the 2\_HSM condition test day indicated that three of the five positions did not record all ten stimuli. Although other participants were included with individual missing points, the combination of missing data points on one day and missing data entirely from another day led to the decision to remove results from participant 11 from further analysis in an effort to simplify analysis and maintain a balanced design as much as possible. No other data were discarded.

Table 2

*Descriptive Statistics*

Variable	<u>Males</u> ( $n = 4$ )		<u>Females</u> ( $n = 11$ )	
	Mean	Standard Deviation	Mean	Standard Deviation
Age (years)	28.25	7.22	23.18	2.44
Weight (lbs)	172.75	7.23	138.27	11.23
Height (in)	71.60	3.20	60.36	4.79
R Arm Length (cm)	77.75	4.13	68.73	2.14
L Arm Length (cm)	77.75	4.13	68.64	2.31

**H-reflex Amplitude**

There was no evidence of an interaction between HSM condition and HP,  $F(8,156) = .74$ ,  $p = .65$ , therefore main effects were examined for significance. The main effect for HSM condition was also not significant  $F(2, 26) = 2.41$ ,  $p = .11$ . There was a significant main effect for HP  $F(4, 156) = 3.54$ ,  $p < .01$  (Table 3). A post hoc analysis using the Tukey-Kramer multiple comparison test showed that left rotation was significantly different from loaded neutral ( $p < .05$ ). The mean difference from baseline, across all HSM conditions, for left rotation was smaller (0.0042 mV) than loaded neutral (0.1717 mV). Examination of the individual HSM condition means (Table 4) helped determine the source of the significance. In the 1\_HSM condition in loaded neutral, there was a mean difference of 0.30 indicating an overall increase in H-reflex amplitude. Conversely, in the 2\_HSM condition, left rotation showed a -0.20 mean difference indicating an overall decrease in H-reflex amplitude compared to neutral.

Table 3

*Two-Factor Split Plot ANOVA Summary Table for H-reflex Amplitude*

Fixed Effects					
Source	df	SS	MS	F	p
HSM	2	3.263	1.632	2.41	.11
HP	4	0.820	0.205	3.54	.01
HSM x HP Interaction	8	0.345	0.043	0.74	.65
Error	156	9.039	0.058		

*Two-Factor Split Plot ANOVA Summary Table for H-reflex Amplitude*

Random Effects					
Source	df	SS	MS	F	p
Participant	13	9.866	0.759	13.10	<.0001
Error	26	17.612	0.677		

Table 4

*Descriptive Statistics for Normalized H-reflex Amplitude (mV) by HSM and HP*

Variable	<u>N HSM</u>		<u>1 HSM</u>		<u>2 HSM</u>	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Flexion	0.07	0.37	0.19	0.45	-0.14	0.34
Extension	0.12	0.35	0.32	0.57	-0.06	0.47
Left Rotation	0.08	0.31	0.10	0.34	-0.17	0.36
Right Rotation	0.10	0.34	0.32	0.42	-0.01	0.51
Neutral	0.12	0.52	0.30	0.52	0.09	0.50

N = 14

### **Post Hoc Analyses for H-reflex Amplitude**

The stated hypotheses specifically refer to differences between HSM\*HP interactions. These hypotheses were assessed by calculating effect sizes using the differences of Least Squares means output which gives estimate means and standard error for the different treatment combinations (Table 5). An effect size of 0.2 is considered small, 0.5 moderate, and 0.8 large. Sabbahi and Abdulwahab (1999) had effect sizes ranging from 0.42 to 1.33.

**Hypothesis 1.** The first hypothesis examined the effect of HSM on the expected change in amplitude from neutral to flexion. The mean amplitude decreased in flexion compared to neutral in both N\_HSM and 1\_HSM, with a larger decrease occurring in the low-weight moment helmet than in no helmet. The effect size was small ( $d = 0.19$ ), but indicates that the hypothesis was correct.

**Hypothesis 2.** The second hypothesis compared the change in amplitude in neutral to flexion between the 2\_HSM condition and the 1\_HSM condition. H-reflex amplitude also decreased in flexion compared to neutral when wearing the 2\_HSM condition. This was a larger decrease in the 2\_HSM condition than occurred from neutral to flexion in the 1\_HSM condition ( $d = 0.34$ , small).

**Hypothesis 3.** The third hypothesis addressed the change in amplitude in extension relative to neutral comparing N\_HSM to the 1\_HSM condition. Amplitude did not change from neutral to extension in either condition.

**Hypothesis 4.** The fourth hypothesis compared change in amplitude for extension between the 1\_HSM condition and the 2\_HSM condition. The H-reflex amplitude

decreased from neutral to extension in the 2\_HSM condition. This resulted in a moderate effect size ( $d = 0.49$ ).

**Hypothesis 5.** The fifth hypothesis compared change in amplitude from neutral to left rotation between N\_HSM and 1\_HSM conditions. There was a non-detectable decrease in amplitude in the N\_HSM condition, and a more apparent decrease in the 1\_HSM condition. The degree of change between the 1\_HSM condition and the negligible mass condition was moderate ( $d = 0.48$ ).

**Hypothesis 6.** The sixth hypothesis compared change in amplitude for left rotation between the 1\_HSM and 2\_HSM conditions. There was a larger decrease in amplitude in left rotation for the 2\_HSM condition than the 1\_HSM condition ( $d = 0.16$ ).

**Hypothesis 7.** The seventh hypothesis assessed the amplitude change occurring in right rotation between the N\_HSM and 1\_HSM conditions. There was a negligible decrease in amplitude from neutral to right rotation for the N\_HSM condition, and a negligible increase in amplitude from neutral to right rotation in the 1\_HSM condition ( $d = -0.11$ ).

**Hypothesis 8.** The eighth hypothesis assessed right rotation changes between the 1\_HSM condition and the 2\_HSM condition. Amplitude decreased in the 2\_HSM condition compared to the negligible increase in the 1\_HSM condition ( $d = 0.32$ , small).

**Hypothesis 9.** The ninth hypothesis compared the H-reflex amplitude in neutral between the N\_HSM and 1\_HSM conditions. H-reflex amplitude was higher in the 1\_HSM condition than in the N\_HSM condition ( $d = -0.44$ , small).



**Hypothesis 10.** The tenth hypothesis assessed amplitude in neutral between the 2\_HSM condition and the 1\_HSM condition. The amplitude was much lower in the 2\_HSM condition than in the 1\_HSM condition ( $d = 0.50$ , moderate).

Table 5

*Effect Sizes for Normalized H-reflex Amplitude Between HSM Conditions*

	<u>1_HSM to N_HSM</u>	<u>2_HSM to 1_HSM</u>
Variable	Effect Size	Effect Size
Flexion	0.19	0.34
Extension	-0.07	0.49
Left Rotation	0.48	0.16
Right Rotation	-0.11	0.32
Neutral**	-0.44	0.50

Note. Effects Size was calculated by the position-mean – neutral-mean/SD (calculated from LSMEANS SE). \*\*Neutral effect sizes calculated by the 1<sup>st</sup> condition mean – 2<sup>nd</sup> condition mean/SD.

### Covariance

Right Sternocleidomastoid (RSCM) RMS was calculated and assessed as a possible covariate for H-reflex amplitude. However, the correlation between RSCM and H-reflex amplitude was very low ( $r = -.04$ ,  $p = .52$ ), and therefore was determined to not be appropriate for use in an ANCOVA.

### H-reflex Latency

**Hypothesis 11.** There was no significant change in H-reflex latency (Table 6) related to HSM condition  $F(2, 156) = 1.20, p = .32$ , confirm stated hypothesis 11.

**Hypothesis 12.** There was also no significant change in H-reflex latency related to HP  $F(4, 156) = 1.47, p = .21$ , confirming stated hypotheses 12 (Table 7).

Table 6

*Descriptive Statistics for H-reflex Latency (ms) by HSM and HP*

Variable	<u>N HSM</u>		<u>1 HSM</u>		<u>2 HSM</u>	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Flexion	17.65	2.05	17.57	2.20	17.85	2.26
Extension	17.61	1.99	17.31	2.18	17.99	2.35
Left Rotation	17.45	2.05	17.58	2.08	17.92	2.24
Right Rotation	17.61	1.98	17.45	2.18	17.85	2.41
Neutral	17.66	1.92	17.27	2.11	17.62	2.15

Table 7

*Two-Factor Split Plot ANOVA Summary Table for H-reflex Latency*

Fixed Effects					
Source	df	SS	MS	F	<i>p</i>
HSM	2	5.436	2.718	1.20	.319
HP	4	0.907	0.227	1.47	.214
HSM x HP Interaction	8	2.122	0.265	1.76	.089
Error	156	22.966	0.147		

*Two-Factor Split Plot ANOVA Summary Table for H-reflex Latency*

Random Effects					
Source	df	SS	MS	F	<i>p</i>
Participant	13	811.859	62.451	26.73	<.0001
Error	26	60.737	2.336		

## Gender

Analyses were repeated controlling for gender and found that there were no significant effects of HSM  $F(2, 192) = 1.50, p = .40$ , or HP  $F(4, 192) = 1.19, p = .317$ , on amplitude (Table 8). Nor were there any significant effect of HSM  $F(2, 192) = 1.25, p = .45$ , or HP  $F(4, 192) = 0.06, p = .99$ , on latency (Table 9).

Table 8

*Two-Factor Split Plot ANOVA Summary Table for H-reflex Amplitude Blocking by Gender*

Fixed Effects					
Source	df	SS	MS	F	<i>p</i>
HSM	2	1.627	0.814	1.50	.40
HP	4	0.820	0.205	1.19	.32
HSM x HP Interaction	8	0.345	0.043	0.25	.98
Error	192	33.061	0.172		

*Two-Factor Split Plot ANOVA Summary Table for H-reflex Amplitude Blocking by Gender*

Random Effects					
Source	df	SS	MS	F	<i>p</i>
Gender	1	2.374	2.374	3.14	.05
Error	2	1.083	0.541		

Table 9

*Two-Factor Split Plot ANOVA Summary Table for H-reflex Latency Blocking by Gender*

Fixed Effects					
Source	df	SS	MS	F	<i>p</i>
HSM	2	14.813	7.407	1.25	.45
HP	4	0.865	0.216	0.06	.99
HSM x HP Interaction	8	2.072	0.259	0.07	1.00
Error	192	741.936	3.864		

*Two-Factor Split Plot ANOVA Summary Table for H-reflex Latency*

Random Effects					
Source	df	SS	MS	F	<i>p</i>
Gender	1	141.729	141.729	23.83	.04
Error	2	11.897	5.948		

## Range of Motion

Cervical spine range of motion was measured via the CROM system with no HSM, and also recorded at baseline via the InterSense InertiaCube™ mounted on crown of the test helmet. Paired samples t-tests were used to determine if the ROM achieved without the helmet was the same as the ROM achieved while wearing the helmet. ROM was significantly lower when wearing the helmet in extension and right rotation ( $p < .001$ ). Flexion and left rotation also showed decreased ROM with the helmet, but not significantly (Table 10).

The 1\_HSM and 2\_HSM conditions were configured using a standard HGU-56/P Army flight helmet. These helmets are custom fit for aviators to maximize comfort and ensure proper wear during use. There were three standard sizes available for use in this study, and the best fit was chosen for each participant. The helmet moved during the testing, particularly in the 2\_HSM condition when it slid forward significantly on the forehead. This provided inconsistent positioning and potentially added an additional external stimulus as the participants continued to reposition the helmet during testing. Every effort was made to control for head positioning between HSM conditions. The InterSense InertiaCube™ was intended to provide auditory feedback to the participant to direct them into the same head position regardless of loading condition. However, the cube feedback was dependent on the position of the helmet, and as stated previously, the helmets moved on the head during the testing. The cubes gave inconsistent feedback, and participants were subsequently instructed to go to their maximum end range of motion for each position. This could vary between days due to individual musculoskeletal properties.

Table 10

*Range of Motion*

Variable	<u>CROM</u>		<u>InterSense InertiaCube™</u>	
	Mean	Standard Deviation	Mean	Standard Deviation
Flexion	-54.04	10.76	-55.85	11.03
Extension	72.13	14.05	58.53	10.67
Left Rotation	-74.53	17.09	-68.21	10.77
Right Rotation	81.47	8.39	65.30	11.41
Sub-Occipital Flexion	-13.07	8.28	NA	NA
Sub-Occipital Extension	44.40	8.19	NA	NA
Right Lateral Flexion	-47.38	10.36	NA	NA
Left Lateral Flexion	45.71	10.78	NA	NA

**NRS-11**

The NRS-11 pain scale was used to rate neck pain at baseline each day, and during each phase of the testing. A two-way Split-plot ANOVA with repeated measures was used to determine if there was a significant effect of HSM condition and phase on perceived neck pain. The results (Table 11) indicated that there was a significant main effect for phase on NIRS-11 score ( $p < .0001$ ). Follow-up analysis indicated that NIRS-11 score in phases 4 and at the completion of testing was significantly higher than the baseline and the first two phases of testing. The NIRS-11 reported scores ranged from 0 to 6. An NRS-11 score of 7 or higher would have required stopped testing. The score of 6 was given once by one individual at the completion of testing under the 2\_HSM condition. Most participants indicated 0 to 3 for all HSM conditions.



Table 11

*Range Values for Reported NIRS-11 Scores*

Variable	<u>N HSM</u>		<u>1 HSM</u>		<u>2 HSM</u>	
	Min	Max	Min	Max	Min	Max
Baseline	0	0	0	0	0	0
Phase 1	0	1	0	2	0	1
Phase 2	0	1	0	2	0	3
Phase 3	0	2	0	3	0	6
Phase 4	0	2	0	3	0	6
Completion	0	3	0	3	0	6

Note. The NIRS-11 reported values of 6, on a scale of 0 to 10, were given for pressure on the forehead, not neck pain.

## **CHAPTER FIVE**

### **Discussion**

#### **Introduction**

The H-reflex was recorded in male and female volunteers, ages 20-39 years, under three different HSM conditions in five different head positions. The study design was a split-plot with HSM and HP each randomized according to a RCB convention using participant as a blocking variable. Each HSM condition was tested on a different day with a minimum of 24 hrs in between test days. Ten electrical stimuli were applied at each HP for each HSM condition. The recorded values for H-reflex amplitude and latency were averaged for further analysis. The H-reflex amplitude was normalized by subtracting the baseline amplitude value recorded at the start of each test day.

#### **H-reflex Amplitude**

The purpose of the current investigation was to determine the acute effect of added HSM on the H-reflex amplitude and latency. Testing was conducted under three HSM conditions in order to with the hopes of combining the research questions of two key studies by Sabbahi and Abdulwahab (1999) and Al Rowayeh et al. (2010) and their colleagues. Sabbahi and Abdulwahab assessed the effect of head position on the H-reflex with no added HSM, while Al Rowayeh et al. examined the impact of HSM in the neutral head position. The present investigation aimed to assess the combined effect of HSM and head position.

The goal of testing with the negligible mass condition was to recreate previous results from the Sabbahi and Abdulwahab (1999) study and to provide a baseline for comparison for the two weighted conditions. The results of the present investigation were mixed with regard to recreating previous results. As with the Sabbahi and Abdulwahab study, flexion showed

decrease in H-reflex amplitude compared to neutral. However, whereas the Sabbahi and Abdulwahab study found H-reflex amplitude increased in extension, left rotation and right rotation; the present study found negligible decreases in amplitude for extension, left rotation and right rotation. The lack of similar results in the negligible mass condition could be a result of the small sample size.

It was predicted that the addition of HSM would alter the expected results in the negligible mass condition. The expected changes were presumed to be linear in that the low-weight moment condition would have a measurable impact, and the high-weight moment condition would show the changes in the same direction, but with a greater magnitude than the low weight-moment condition. In fact, the results of the present investigation show mixed results when comparing the two weighted HSM conditions.

Flexion caused a detectable decrease in both the low-weight moment and high-weight moment conditions. Amplitude decreased by 40% in the N\_HSM condition compared to a 50% decrease in the 1\_HSM condition. In contrast, there was a 260% decrease in amplitude in the 2\_HSM condition. This indicates that the addition of HSM may, in fact, increase the mechanical compression of the nerve root space as was theorized by previously.

While there was no change in H-reflex amplitude in extension in either the N\_HSM condition or the 1\_HSM condition, there was a detectable decrease in amplitude in the 2\_HSM condition. It was hypothesized that the expected increase in amplitude in extension would be mitigated by the addition of HSM. The detectable decrease in amplitude in 2\_HSM could be indicative of this mitigation, but it is difficult to make comparisons without measurable changes in the other two conditions. An amplitude decrease of 170% in the 2\_HSM condition and no

change in 1\_HSM condition at face value would seem consistent with the hypotheses that amplitude increases would be mitigated. However, since there was also no change in the N\_HSM condition, there is little confidence of this effect, particularly with the 1\_HSM condition.

The argument is slightly more convincing with left rotation which showed a consistent decrease in amplitude as mass increased. Amplitude decreased by 34% in the N\_HSM condition and 67% in the 1\_HSM condition. In comparison, there was a 290% decrease in amplitude in the 2\_HSM condition. Again, caution is used when interpreting these results because amplitude showed a negligible decrease in the N\_HSM condition rather than the expected increase.

Right rotation resulted in a small decrease in amplitude for the N\_HSM condition (18%) which is inconsistent with the Sabbahi and Abdulwahab (1999) study. There was a slight increase in amplitude under the 1\_HSM condition (4%). Amplitude decreased by 113% in the 2\_HSM condition. The slight increase in amplitude in the 1\_HSM condition could be a result of amplitude facilitation from increased muscle activity in the neck. Al Rowayeh et al. (2010) found that added mass in a neutral head position was linked to increased amplitudes. The fact that this increase only occurred in right rotation may be related to increased muscle activity particularly on the side of the recording. The decrease apparent from 2\_HSM to 1\_HSM indicates that perhaps this slight attenuation is over-ruled by the mechanical compression occurring at the nerve root.

Similarly, amplitude in neutral increased by 150% in the 1\_HSM condition compared to the N\_HSM condition. However, amplitude in neutral decreased by 70% in the 2\_HSM condition compared to the 1\_HSM condition. The additional mass may have provided enough

mechanical compression to counteract the attenuation effect from muscle activity. Al Rowayeh et al. (2010) believed that the addition of HSM facilitated the H-reflex amplitude by increasing the excitability of the central spinal motoneurons. Ali and Sabbahi (2000) also found that loading the spine caused an increase in amplitude which they related to an excitatory response of the central nervous system. An attempt to correlate the increased H-reflex amplitude with increased neck muscle activity was unsuccessful in the present study. This may be due to insufficient contact of the electrode with the muscle. Despite the lack of EMG activity to support this, it is reasonable to think that muscle activity would increase with increased load on the head. The decrease in amplitude with the 2\_HSM condition indicates there may be sufficient mechanical compression occurring to override the excitatory effect which occurs in 1\_HSM.

Al Rowayeh et al. (2010) used a 4.5 kg helmet for their cervical spine loading condition which is heavier than both the 1\_HSM (1.5 kg) and 2\_HSM (3.5 kg) conditions used in this study. However, there is no indication if the helmet used in the Al Rowayeh et al. study had any kind of CG offset, or if the load was centrally located. If the load was centrally located, it does not take into account the potential effect of CG offset on muscle activation and cervical spine mechanics. The present study used two HSM conditions with significant CG offsets in order to best mimic potential helmet configurations which may occur in current helmet usage. The 2\_HSM condition in particular had a CG offset of 4.5 cm forward of the EAM. It is plausible that this change is contributing to decrease in amplitude rather than the increase that Al Rowayeh et al. found at a higher mass.

### **H-reflex Latency**

As expected, there were no significant effects of HSM or HP on latency. Changes in latency are typically associated with chronic nerve injury and demyelination of the nerve itself (Jaberzadeh & Scutter, 2006). Acute compression of the nerve, proposed to be occurring in this study, would not be sufficient to induce alterations in latency. This is consistent with the results of both Sabbahi and Abdulwahab (1999) and Al Rowayeh et al. (2010).

### **Gender Differences**

Gender was examined as a variable effecting both amplitude and latency. Gender was not found to significantly affect either amplitude or latency. This is consistent with research in the field which typically does not control for gender since comparisons are made within participants, and not between.

### **Conclusion**

The combination of HSM and HP showed mixed effects on H-reflex amplitude. The small sample size and possible variance issues within the measure made it difficult to make any concrete conclusions regarding either HSM, HP or the combination of the two factors. There is some indication that added mass, particularly the 2\_HSM condition has a mitigating effect on the H-reflex amplitude. Amplitude showed measurable decreases in all positions under 2\_HSM when compared to the N\_HSM and 1\_HSM conditions. H-reflex latency showed no significant changes related to either HSM or HP confirming that any effect from those two factors would be acute in nature and not sufficient to alter the nerve health itself. It is important to further investigate the potential effects of HSM and HP on nerve function particularly if increased CG offset is a significant factor in changing amplitude. As has been noted, performance degradation

has been linked with increased HSM. It is possible that decreased nerve function is linked with decreased performance potentially more-so when the helmet is worn with NVGs in the forward position resulting in a forward CG offset.

## **Recommendations**

A number of factors could have contributed to the small effects seen, and inconsistencies between the present study and previous work. The testing environment was not isolated from external noise, vibration, and distraction. The H-reflex is known to be sensitive to internal and external stimuli and is recommended to be tested in a controlled environment. Different techniques for eliciting the H-reflex are available and may provide additional stability to the reflex. Future work should consider better helmet fit, or mass combinations that are more stable on the head. It would be helpful to have a visual of what is actually happening at the nerve root and intervertebral foramen in the different head positions, therefore positional MRI scans should be considered. Direct comparisons are not possible between loading conditions used in this study and the one used in the Al Rowayeh (2010) study. Incorporating a 4.5 kg helmet, with a negligible CG offset, would be useful in determining the effects of CG offset on H-reflex amplitude. Despite the small effect sizes, there is some indication that increased HSM can alter the H-reflex amplitude in different head positions. A larger sample size is important to fully determine if these effects are significant and potentially indicative of future issues in a military population.

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**APPENDIX A**  
**Medical History Questionnaire**

### Medical History Questionnaire with Standards

**(Information in Bold Text is for Research Team copy only)**

1. Have you ever participated in the following sports?

	Yes/No	Level of Competition (recreational, varsity/JV, college)	Total Years Played	Last Year Played
Football				
Soccer				
Rugby				
Other				

**For tracking purposes and trend analysis.**

**Only disqualified if participation in helmeted sport within the last year.**

2. Have you ever played a sport which required you to wear a helmet?

Circle One:        Yes    No

If yes, please explain

---



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**Same standards as question 1**

3. Are you currently serving in the active duty military?

Circle one:        Yes    No

**If yes, then NOT eligible**

4. Are you currently serving in the military in a reserve/national guard status?

Circle one:        Yes    No

If yes, are you in a combat or combat support military occupational specialty (MOS)?

Circle one:        Yes    No

Please list MOS: \_\_\_\_\_



**If yes to both, then NOT eligible**

5. Have you ever served in the military?

Circle one:            Yes    No

If yes, were you in a combat or combat support military occupational specialty (MOS)?

Circle one:            Yes    No

Please list MOS: \_\_\_\_\_

**If yes to both, then NOT eligible**

6. Have you ever deployed to a combat theatre i.e. Iraq or Afghanistan, regardless of MOS?

Circle one:            Yes    No

**If yes, then NOT eligible**

7. Have you ever had a job which required you to wear a helmet or device on your head for extended periods of time (greater than 30 minutes)?

Circle one:            Yes    No

If yes, please explain (type of job, time frame, type of helmet, etc.)

\_\_\_\_\_  
\_\_\_\_\_

**If yes, and job was for longer than 1 year then NOT eligible****If yes, and helmet weight estimate is more than 1 lb then not eligible****If no, then eligible**

8. Do you ride a motorcycle or moped?

Circle one:            Yes    No

If yes, do you wear a helmet?    Yes    No

How many miles do you ride a week? \_\_\_\_\_

**If yes, and more than 2 hrs per week, then NOT eligible**

**If no, then eligible**

9. Do you participate in any recreational activities (i.e., bicycling, rollerblading/skating, skateboarding, horseback riding, kayaking, snowboarding) during which you wear a helmet?

Circle                      Yes    No

If yes, how often do you wear your helmet? \_\_\_\_\_

**If yes, and more than 5 hrs per week, then NOT eligible****If no, then eligible**

10. Have you ever been diagnosed with a vertebral fracture (spondylosis, spondylolisthesis, or spondylolysis)?

Circle one:              Yes    No

**If yes, then NOT eligible**

11. Have you ever been diagnosed with a bulging or prolapsed cervical disc?

Circle one:              Yes    No

**If yes, then NOT eligible**

12. Have you ever been diagnosed with a neck sprain or strain?

Circle one:              Yes    No

If yes, please explain

\_\_\_\_\_  
\_\_\_\_\_

**If within last year then NOT eligible****If more than a year ago and not severe then eligible**

13. Have you ever had any neck injury not covered above?

Circle one:              Yes    No

If yes, please explain

\_\_\_\_\_  
\_\_\_\_\_

**Researcher's discretion with consultation of study physician, depends on response**

14. Have you ever experienced neck pain

Circle one:        Yes    No

If yes, please describe frequency and duration

---



---

14a. How often does the neck pain occur i.e. daily, weekly, only occasionally, only when conducting certain extended activities (reading, computer work)?

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---

14b. When did the pain last occur?

---



---

14c. Describe the nature of the pain i.e. sharp, dull/achy, sore.

---



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14d. Do you have any idea what causes the pain?

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---

**Researcher's discretion with consultation of study physician, depends on response**

15. Have you ever experienced numbness or tingling in your legs, feet, toes, arms, hands, or fingers?

Circle one:        Yes    No

If yes, please explain

---



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15a. Does the numbness or tingling occur more often and/or is it more severe than the normal foot/hand falling asleep feeling?

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**Researcher's discretion with consultation of study physician, depends on response**

16. Have you ever experienced unexplained loss of strength in your hands, arms, or shoulders?

Circle one:        Yes    No

If yes, please explain

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**Researcher's discretion with consultation of study physician, depends on response**

17. Have you ever been diagnosed with any type of nerve dysfunction, degeneration, or disease?

Circle one:        Yes    No

If yes, please explain

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**If yes, then NOT eligible**

18. Has anyone in your immediate family ever been diagnosed with nerve dysfunction, degeneration, or disease?

Circle one:        Yes    No

If yes, please explain

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**If yes, then NOT eligible**

19. Have you ever been diagnosed with any type of arthritis?

Circle one:        Yes    No

If yes, please explain type (i.e. rheumatoid, osteoarthritis) and location (i.e. shoulder, knee, wrist).

---

---

**If arthritis located in cervical spine, shoulder, elbow, wrist or hand, then NOT eligible.**

20. Do you currently participate in neck specific strengthening exercises?

Circle one:        Yes    No

If yes, please list type and frequency

---

---

**20a. Have these exercises been prescribed by a physician, athletic trainer, or physical therapist to address a specific neck injury or issue?**

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**Researcher's discretion with consultation of study physician, depends on response**

Reviewed by:

---

Typed Name

---

Signature

---

Date

**APPENDIX B**  
**Anthropometric Measurement Data Collection Sheet**

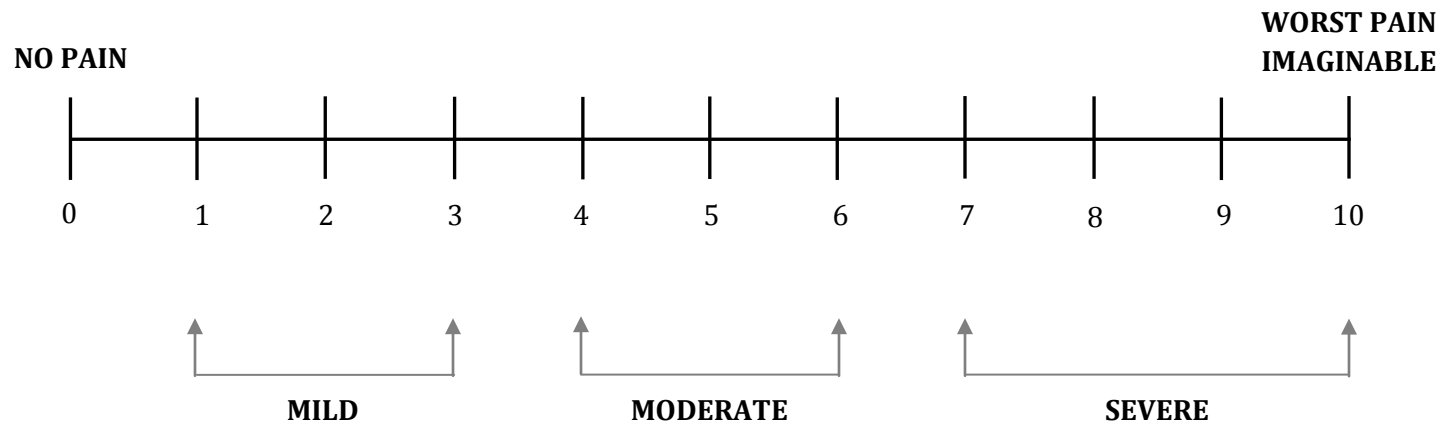
Anthropometrics	
	Participant ID # _____
<b>CROM</b>	
<b>Suboccipital:</b> Resting Posture (Neutral) _____  Flexion _____  Extension _____	<b>Cervical:</b> Flexion _____  Extension _____
<b>Lateral Flexion:</b> Resting Posture (Neutral) _____  Left _____  Right _____	<b>Rotation:</b> Left _____  Right _____
Height _____	Weight _____
<b>Arm Length:</b> Left _____  Right _____	

**APPENDIX C**  
**Numerical Rating Scale (NRS-11)**



## Numerical Rating Scale (NRS-11)

Circle the **number** corresponding with your current level of neck pain.



**APPENDIX D**  
**Informed Consent**

US Army Aeromedical Research Laboratory  
**CONSENT TO PARTICIPATE IN RESEARCH**

Title of Protocol: Effects of Head Position and Head-supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle of Healthy Individuals.

Principal Investigator: Carol Chancey, Ph.D

Co-Investigators: Bethany L. Shivers, M.S.

Funding Source(s)/Sponsor: US Army Aeromedical Research Laboratory

## INTRODUCTION

You are being asked to participate in a research study conducted at the US Army Aeromedical Research Laboratory (USAARL) by Dr. Carol Chancey and Bethany Shivers because you have expressed an interest in participating in this study. Your participation in this study is voluntary. It is important that you read what is written below, and ask questions about anything you do not understand. You may want to talk with your family, friends, or others to help you decide if you want to be part of this study. When you feel that your questions have been answered, you will be asked if you agree to be part of the study or not. If you agree, you will be asked to sign this consent form. You will be given a copy of this form to keep.

## WHY IS THIS RESEARCH STUDY BEING DONE?

The purpose of this research study is to determine the influence of head-supported mass (HSM) and/or head position on nerve function measured in a muscle in the forearm. For the purpose of this study, HSM refers to a military helmet and any additional equipment that might be mounted to it. Recent studies have shown that HSM can lead to deterioration of the spine. This is a particular issue in military populations where Soldiers and aviators are required to wear HSM for extended periods while maintaining awkward head positions during the performance of their duties. The results of this study may help with injury prevention in our military populations.

## WHAT WILL HAPPEN DURING THIS STUDY?

If you agree to participate in this study, you will be asked to do the following:

You will be seated in a chair while wearing the helmet or head-harness for up to 45 min. You will have small electrodes attached to your neck to record muscle activity and additional electrodes attached to your right arm to record nerve function. You will be directed to move your head from neutral to four different head positions multiple times. Each head position will be held for 30 sec to 1 min. The last time you hold each head position, a small electrical stimulus will be applied to a nerve in your arm and the resulting muscle activity will be recorded for analysis. Neck strength testing will be conducted as part of the baseline testing (today).

Title: Effects of Head Position and Head-supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle of Healthy Individuals.  
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Additional procedures/measures include a medical history questionnaire, height/weight and range of motion.

## Overview

Prior to the start of this study, we will first need to determine eligibility to participate by having you complete a medical history questionnaire. Current or former military personnel, individuals who often wear helmets, currently play have played contact sports within the last year, or have any current neck or arm injuries are not the target research group for this study and therefore will be excluded.

The purpose of the medical history questionnaire is to identify specific issues that could affect the outcome of this particular study. The medical history questionnaire is not meant to serve as a general health review for physical purposes. However, if any critical medical issues are identified the study physician may recommend that you see your personal physician for further care.

Your age will be verified from a picture ID (either driver's license or other picture ID with date of birth). Once it is determined that you are eligible to participate, you will be fitted for the HGU/56-P flight helmet and an adjustable head-harness. These are the devices which will be used to test the different HSM conditions as well as mount the targeting equipment.

## Testing Procedures

The testing will be conducted on three different days over the course of a week. A different HSM condition will be tested each day. Each test day will require approximately 1.5 hours of your time (Table 1) with you wearing the HSM for approximately 45 minutes per test day. The testing will require you to hold your head in specific positions while a small electrical stimulus is applied to a nerve in your arm. This stimulus will cause the muscle in your forearm to twitch. That muscle twitch will be recorded through adhesive electromyography (EMG) electrodes placed on your arm.

To elicit the H-reflex, we will start at a very low stimulus intensity that you likely won't even feel. We will increase the intensity until we begin to see the response that we are looking for. As we increase the intensity, you will likely begin to feel the stimulus directly under the electrode but it won't be painful – it will feel like a pin-prick. As the intensity increases further, you may feel the stimulus run down your forearm and into your fingers. You may also see your fingers or wrist move because of the muscle twitch. At the peak intensity, the stimulus will feel like a strong carpet shock. This may be uncomfortable, but most individuals find this discomfort tolerable and not painful enough to stop testing. This high stimulus intensity will only be used a few times to determine the maximum response. It is important that we find the maximum response because this allows us to set a much lower consistent stimulus intensity level that can be standardized across all conditions. We will conduct the majority of the testing at a stimulus intensity that produces reflex at 20% of this maximum response. The intensity will be at a significantly lower level which you will likely be able to feel, but it should not be painful at all.

The total number of stimuli you will receive per day will be approximately 120. It may take up to 20 stimuli to determine the maximum value needed. A large portion of the 20 to 40 stimuli given

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during this time might not even be felt. We intentionally start low and work our way up to ensure that we do not cause pain or miss the desired level we are seeking. The remainder of the stimuli will be given at the lower level described above.

EMG electrodes will also be placed on your neck in order to record neck strength before and after each test session. Throughout the testing, you will be asked to indicate your level of discomfort using a numerical rating scale (NRS-11). Discomfort will be rated from 0 to 10 with 0 being no discomfort at all and 10 being the worst pain imaginable. It is highly unlikely that you will experience any significant discomfort during this study. However, if at any time you rate your discomfort as severe, the testing will be immediately stopped. See the attachment for more detail on the research procedures.

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**Table 1: Study Schedule**

Day	Session	Activities
1(today)	In-processing	Informed consent Medical history questionnaire Baseline H-reflex testing Baseline EMG – Maximum Voluntary Contraction (MVC) and time-to-fatigue Anthropometry Helmet fitting
2	Testing	1 of 3 HSM configurations tested in each head position
3	Rest	
4	Testing	2 of 3 HSM configurations tested in each head position
5	Rest	
6	Testing	1 of 3 HSM configurations tested in each head position

**Post-test Procedures**

You will be provided a handout detailing stretches to complete two to three times throughout the next day to alleviate any potential neck soreness which might be experienced. We recommend that you do these stretches later in the day of each test day as well as during the rest days in between testing days. You will be sent a 24-hour post-test email asking you to report any adverse side effects.

**WHAT ARE THE POTENTIAL RISKS AND DISCOMFORTS FROM BEING IN THIS RESEARCH STUDY?**

Given that you will be wearing HSM configurations while holding your head in specific positions, there is a small (5-10%) chance that you will experience some muscle soreness. This soreness will be similar to that experienced during a strength training workout and will be mitigated by allowing a day between test sessions and pre- and post-test stretching. There is a very small chance (less than 5%) that you will experience a muscle cramp during testing. Such an event would be uncomfortable, but carry no long-term effects. Should a cramp occur, testing would be immediately stopped and you will be assisted in stretching the affected area. In the development of these testing procedures, no one has ever experienced a muscle cramp related to the testing.

The HSM conditions used for this study are similar to those used in previous research here at USAARL. Isolated neck discomfort may occur during the testing process; if you report a neck discomfort rating of 7 or higher on the NRS-11 scale, testing will be immediately halted. The

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NRS-11 uses 0 to represent no discomfort and 10 to represent the worst pain imaginable. Scores from 1 to 3 will represent mild discomfort, 4 to 6 will represent moderate discomfort, and 7 to 10 will represent severe discomfort. You will be allowed to return to a comfortable position and the test apparatus will be removed. You will perform a series of neck and upper-back stretches prior to the start of the study which should minimize any post-study soreness. Again, in the development of these procedures, no one ever indicated a discomfort rating of 7 or higher. There is a small risk of discomfort, heat, irritation or itching at the electrode site from the adhesive. Whenever possible, latex-free materials will be used.

There is no risk of injury from the H-reflex or EMG equipment to be used in this study. The preparation for electrode placement may cause slight skin irritation. There is no risk of electrocution while using this equipment. Both the H-reflex and the EMG devices are isolated from the domestic power supply through a series of safety circuits. There may be some discomfort associated with the H-reflex and M-wave maximum testing. The discomfort can be likened to the sensation of a "carpet shock" as the electrical stimulus is applied. This sensation is considered less uncomfortable than a needle stick for a blood draw and lasts less than one second. The electrical stimulus does not cause any lingering or long-lasting effects. The majority of the testing will be conducted using a stimulus that will be perceptible but not painful to you.

#### **WHAT ARE THE POSSIBLE BENEFITS FROM BEING IN THIS STUDY?**

There are no benefits to you from participating in this research. The information that we learn in this study may help us understand the long-term effects of HSM on the cervical spine and the nervous system. This information may assist in the design of military helmets and helmet mounted systems. This will also help determine methods for prevention of future negative musculoskeletal effects in military personnel.

#### **WHAT ALTERNATIVE OPTIONS TO PARTICIPATION ARE AVAILABLE TO ME?**

The only alternative is to not participate in the study.

#### **WILL I HAVE TO PAY FOR ANYTHING IF I TAKE PART IN THIS RESEARCH STUDY?**

There will be no cost to you for participation in this study.

#### **WILL I BE PAID TO TAKE PART IN THIS RESEARCH STUDY?**

University of Arkansas student participants may be offered extra credit in college courses by University professors and instructors. Extra credit is offered at the discretion of the individual professors. Study investigators have no control or input regarding quantity of extra credit if it is offered.

#### **WHAT HAPPENS IF I AM INJURED AS A RESULT OF TAKING PART IN THIS RESEARCH STUDY?**

If you are injured because of your participation in this research and you are a DoD healthcare beneficiary (e.g., military spouse or dependent), you are entitled to medical care for your injury

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within the DoD healthcare system, as long as you remain a DoD healthcare beneficiary. This care includes but is not limited to free medical care at Army hospitals or clinics.

If you are injured because of your participation in this research and you are not a DoD healthcare beneficiary, you are entitled to free medical care for your injury at an Army hospital or clinic. It cannot be determined in advance which Army hospital or clinic will provide care. If you get care for research-related injuries outside of an Army hospital or clinic, you or your insurance will be responsible for medical expenses.

Transportation to and from Army hospitals or clinics will not be provided. No reimbursement is available if you incur medical expenses to treat research-related injuries. No compensation is available for research-related injuries. You are not waiving any legal rights. If you believe you have sustained a research-related injury, please contact the PI, Dr. Carol Chancey. If you have questions, please contact Bethany Shivers at 256-655-3446 (cell) or 334-255-6894 (office) or you can contact Dr. Chancey at 334-255-6952.

#### **HOW WILL YOU PROTECT MY PRIVACY AND THE CONFIDENTIALITY OF RECORDS ABOUT ME?**

The principal investigator will keep records of your participation in the study. To protect your privacy, any of your study related records [data, photos, video] will be labeled or "coded" with an assigned study participant number, that will not include your name or social security number. The associate investigator, Bethany Shivers, will keep the document connecting your participant number and your research related records in a locked cabinet located in a locked office. The principal investigator and associate investigator are the only individuals who will be able to match your study participant number with any of your personal identifying information. The data will be transmitted and stored electronically by means of a secure server. The data will be stored in a database on a password-protected Government intranet. Access to the database will be restricted to the study investigators, research technicians (who will organize the data files for analysis), representatives of the USAARL, the University of Arkansas IRB, USAMRMC, and other government agencies who may have access to the study data as part of their duties and part of their responsibility to protect human subjects in research.

As this protocol is serving as the dissertation project for a student at the University of Arkansas, it must also be noted that any research records associated with the University of Arkansas are releasable under the Freedom of Information Act if they are requested. If legally requested, the University is required to release data files and a list of participants. However, the University will not release any information linking an individual participant to their data i.e., it will be impossible to determine which participant is associated with which data set.

#### **Consent for Use of Photos and Video**

Photographs and video may be taken during data collection. These would be useful for both presentation purposes as well as ensuring accuracy and consistency in future protocol replication. Should these images be used for presentation or publication purposes, your features will be blurred or masked. When the results of the research are published or discussed

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in conferences, no information will be included that would reveal your identity to others. It is not a requirement to allow these photographs or video to be taken for the research to be conducted.

☐ I grant permission to take photos and videos for use in research related purposes.

☐ I do not grant permission to take photos and video during the research. However, I still wish to participate in the research.

#### WHAT IF I DECIDE NOT TO PARTICIPATE IN THIS RESEARCH STUDY?

Your participation in this research is voluntary. You may decline to participate now or stop taking part in this study at any time without any penalty or loss of benefits to which you are entitled. Deciding not to participate now or withdrawing at a later time does not harm, or in any way affect, your future relationships with USAARL. Any data collected during the course of the experiment will be kept/stored and may be used in the analysis phase of the study, including the data collected prior to your withdrawal from the study.

#### WHAT COULD END MY INVOLVEMENT IN THE STUDY?

The researcher may withdraw you from participating in this study if circumstances arise that warrant doing so. The H-reflex cannot be found in some individuals. This is not a medical concern and does not imply an inherent nerve dysfunction, but it does eliminate the possibility of further participation in the study. If your rating on the NRS-11 neck discomfort rating scale is 7 or higher the testing will automatically be halted. If you experience any side effects including neck pain or discomfort greater than what you consider tolerable for a short period of time, severe itching, heat or discomfort at the electrode sites, or pain associated with the H-reflex testing, greater than you consider tolerable, or if you become ill during testing, you may have to drop out, even if you would like to continue. The researcher will make the decision and let you know if it is possible for you to continue. The decision may be made to protect your health or your safety.

#### WHO SHOULD I CALL IF I HAVE QUESTIONS OR CONCERNS ABOUT THIS STUDY?

If you have questions about your rights as a research volunteer, you may contact the Headquarters, U.S. Army Medical Research and Materiel Command Institutional Review Board at 301-619-6240 or by email to [irboffice@amedd.army.mil](mailto:irboffice@amedd.army.mil).

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**SIGNATURE OF RESEARCH PARTICIPANT**

I have read the information provided above. I have been given an opportunity to ask questions and all of my questions have been answered to my satisfaction.

---

Printed Name of Participant

---

Signature of Participant

---

Date

**SIGNATURE OF PERSON OBTAINING CONSENT**

My signature certifies that the participant signed this consent form in my presence as his/her voluntary act and deed.

---

Printed Name of Person Obtaining Consent

---

Signature of Person Obtaining Consent

---

Date

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## Attachment 1 – Specific Test Procedures

### Testing Overview

Testing will be conducted using three different HSM combinations (figure 1): negligible HSM (N\_HSM), and two conditions with a standard flight helmet modified with weights placed in different locations (1\_HSM and 2\_HSM). Each HSM combination will be tested on a different day. There will be a minimum of 24 hours between each test day to minimize the effects of muscle fatigue or soreness. Neck strength and muscle fatigue will be tested on the first day during baseline testing.



Figure 1. (a) Modified HGU-56/P with added mass and inertia cube and (b) adjustable SPH-4 harness and metal rim for N\_HSM condition.

Each collection day is divided into two sections: exposure period and H-reflex testing. The first section is the 30 min exposure period during which time you will wear the HSM condition and move your head repeatedly to five randomly ordered head positions. The five different positions: neutral, flexion, extension, left rotation, and right rotation. Immediately following the exposure period, the H-reflex testing will be conducted. You will return your head one more time to the five head positions and the H-reflex will be measured in each position. EMG on your neck and perceived pain/discomfort will be recorded throughout the exposure period and the H-reflex testing.

Discomfort will be measured using an 11-point numerical rating scale (NRS-11) which will be reviewed with you before each test session. This scale uses 0 to represent no pain and 10 to represent the worst pain imaginable.

Both the H-reflex and EMG will use electrodes placed on your skin. The skin will be prepared for these electrodes by shaving and cleaning the attachment sites. The H-reflex uses a very brief (less than 2 milliseconds) electrical stimulus to generate a muscle twitch which is recorded using EMG. The stimulus at the upper level of intensity has been compared to a "carpet shock" and has no lingering effects. The majority of the testing will be conducted using a stimulus intensity that you can feel, but is well below what most consider uncomfortable. The H-reflex and EMG are safe systems that have been used in many research studies and in

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rehabilitation clinics. **You are free to stop the testing at any time for any reason without penalty.**

## Test Procedures

### Anthropometric Measures

A number preliminary measurements will be taken including height, weight, left/right arm length, neck circumference, and cervical range of motion (CROM). CROM will be measured using the Cervical Range of Motion Instrument (Performance Attainment Associates), a device designed to measure the angles that your head and neck are held at. All measurement standards will be those used in a US Army anthropometric survey.

### Test Preparation

1. The neck discomfort rating scale will be reviewed with you prior to the start of data collection each day. This scale uses 0 to represent no discomfort and 10 to represent the worst pain imaginable. Scores from 1 to 3 will represent mild pain, 4 to 6 will represent moderate discomfort, and 7 to 10 will represent severe discomfort.
2. If the baseline rating is greater than 3 then you will be excused from further participation on that day.
3. The area where the electrodes will be placed will be prepared by shaving, cleaning and lightly rubbing the site with an alcohol pad and fine sand-paper. This will ensure good contact with the electrode and the skin. The electrodes will be affixed with double-sided tape.
4. The H-reflex stimulus electrode will be placed over your median nerve just above the crease in your elbow. A second electrode will be placed on the back of your arm just above your elbow.
5. The H-reflex recording electrode will be placed over a muscle in your forearm. The location will be found by feeling the surface of your arm and having you perform some movements with your wrist. Once identified, the electrodes will be placed accordingly. A latex-free self-adhesive tape will be wrapped over the electrodes to further minimize electrode movement.
6. The electrodes for the neck EMG will be placed on the left and right side of your neck to record six different neck muscles.
7. You will conduct warm-up stretches in accordance with US Army Field Manual FM 21-20: Physical Fitness Training. These stretches were chosen to specifically target the neck muscles which will be used to perform the movements in the test protocol. The specific stretches are:
  - a. Head/Neck Rotation – You will stand with your feet shoulder-width apart and arms relaxed at your side or with your hands placed on the hips. You will slowly roll your head in a clockwise direction making a complete circle. You will repeat this movement three times clockwise and three times counterclockwise.
  - b. Upper-back stretch – You will stand with your feet shoulder-width apart. Arms will be extended forward at shoulder height. With fingers interlaced and palms facing outward, you will extend the arms and shoulders as far as possible. This position will be held for 10 to 15 seconds (sec) and repeated three times.
  - c. Neck-shoulder stretch – You will stand with your feet shoulder width apart and arms behind the back. You will grab the left wrist with the right hand and pulling down on the left arm with the right. You will simultaneously laterally flex the head

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to the right side. This position will be held for 10 to 15 sec. The stretch will be repeated three times on the right side and then three times on the left side. The right arm will be pulled downward by the left and the head will be laterally flexed to the left side. The stretch will again be held for 10 to 15 sec and repeated three times.

8. Upon completing the stretches, you will be seated in the test chair with your feet flat on the floor so that your knees and ankles are set at 90°. Your arms will be relaxed at your sides with the forearms resting in your lap with the palms up. You should breathe normally during testing, but otherwise try to stay as still as possible.

#### Baseline Testing

1. Baseline values for the H-reflex will be established first. This process will start with the application of a low-level stimulus and increasing the intensity gradually until the desired value is determined. The goal of this portion of testing is to determine 1. If the researchers are able to illicit an H-reflex from you, and 2. the maximum stimulus intensity needed to achieve a maximum reflex. The remainder of the testing will be conducted using a stimulus intensity to elicit an H-reflex of 20% ( $H_{20\%}$ ) of that maximum value. This stimulus intensity is much lower than the maximum intensity determined earlier. Most individuals can feel this stimulus, but do not find it painful at all. It may take up to 20 stimuli to determine this level. Not all of these stimuli will be felt as we will start out low and increase intensity until we achieve the desired effect. Specific head position locations will be established for the neutral head position and for the maximum obtainable positions, that you can reach without assistance or discomfort, for neck flexion, extension, left and right rotation. A device mounted on the head band and helmets will record the coordinates of each position. For the remainder of the testing, you will be asked to recreate these head positions precisely. You will be given auditory cues to assist you in locating these head positions. The following verbal descriptions will be used to direct you into the proper head positions:
  - a. Neutral – sit up straight with your head positioned over your shoulders, eyes looking straight ahead, and chin level with the ground,
  - b. Flexion – touch your chin to your chest,
  - c. Extension – look at the ceiling
  - d. Left rotation – look over your left shoulder,
  - e. Right rotation – look over your right shoulder,
2. You will complete a three-part neck muscle strength assessment. (Harrison et al., 2009). A harness will be positioned on your head. The harness is attached to a load cell which measures your force output. (Figure 3) EMG electrodes will record the activity of your neck muscles while you conduct the three phases of the strength assessment. The assessment will be conducted in flexion, extension and left/right lateral flexion.
  1. Isometric maximum voluntary contraction (MVC): In this phase you will push or pull as hard as you can in the direction of flexion and extension. The strap is fixed to a brace, so your head won't actually move as you conduct each contraction. You will repeat each direction three times for 4 sec each with a 45 sec rest between each repetition. You will have a 3 min rest before you start a new direction. The maximum value of the three trials for each direction will be used as the MVCs.

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2. MVC-EMG calibration curve: In the second phase of testing, instead of a maximal effort, you will gradually increase and then decrease your level of effort against the head strap in each direction. You will start off at 0% and then increase in ten stages until you reach 70% and then you will begin to decrease your level of effort in ten stages until you reach 0% again. A software program will give you a visual cue of when to increase or decrease the amount of strain you put on the head strap. The software will show real-time feedback of the force being exerted and the target zone in the form of a sliding white bar on screen. The target zone will appear green. This process will be repeated for extension and flexion. A 3 min rest will be allowed between each direction.
3. Isometric endurance: For the last phase of testing, you will exert a 70% effort against the head strap and hold it for as long as possible. An onscreen display will again show the target zone with the sliding white bar indicating the level of force being exerted. (Figure 4) When your level of effort falls short of 70% for longer than 2 sec the software will automatically end the trial. The process will be repeated for extension and flexion with a 5 min rest between directions.



**Figure 3: Participant conducting neck MVC measurement.**

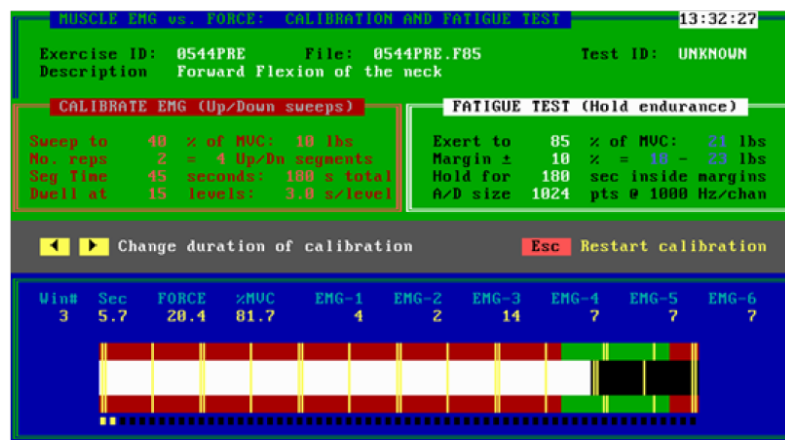


Figure 4: Screenshot of custom developed for isometric endurance testing.

#### Condition Testing (All HSM conditions) – up to 45 min

1. You will remain seated in the test chair, but will don one of the three HSM configurations. You will sit for a 30 min exposure period. The first 25 min of the exposure period will be divided into three equal sections. During each section of the exposure period, you will be randomly guided into all test head positions except for neutral. You will return to neutral between each position. Visual and auditory cues will be given to direct you into the correct positions. The inertia cube on the crown of the HSM configuration will track your head location throughout the movement. The auditory cue is a beeping sound which will be heard as the head approaches the appropriate position. The beeping will be slowest when the head is positioned near neutral. As the head is moved to the correct position the beeping will increase in cadence. When the head is positioned within the allowable window the beeping will stop. You will hold each head position for 30 sec. After 30 sec, you will return the head to a neutral position. Head position order will be randomized for each section. Each head position will be assumed once per section. At the end of the third section, you will remain in the neutral position for an additional five minutes before the H-reflex testing begins. This five minute period will allow you to rest and minimize any carry-over effects of movement and external stimuli on the H-reflex.
2. At the end of the five minute rest period, ten stimuli will be given in the neutral position. You will then be instructed to move your head into four different head positions in random order (Sabbahi & Abdulwahab, 1999). For each condition you will move the head to the end range of motion position and hold it there. The same auditory will be used to assist you in assuming the correct head positions.
3. During each section of the exposure period you will verbally indicate perceived pain/discomfort at least once using the NRS-11.
4. You will hold each head position for approximately 1 min or until a reported score of 7 on the NRS-11.

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5. During the static hold the H-reflex amplitude and latency will be tested in the right arm every 5 sec. Neck muscle activity will also be recorded. A total of ten stimuli will be administered and the reflex recorded for each position.
  6. In the event that the head moves out of the allowed window for position, the auditory cues and the visual directional cues will be present to direct you back to the correct position.
  7. This process will be repeated for each of the remaining head positions.
- Neck muscle activity will be recorded during the exposure period and for each head position during H-reflex testing. The same electrode placements will be used as during the neck strength assessment conducted during baseline testing.

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**APPENDIX E**  
**University of Arkansas IRB Approval and Modification Memoranda**



120 Ozark Hall • Fayetteville, Arkansas 72701 • (479) 575-2208 • (479) 575-3846 (FAX)  
Email: [irb@uark.edu](mailto:irb@uark.edu)

**Research Support and Sponsored Programs  
Institutional Review Board**

January 24, 2011

**MEMORANDUM**

TO: Bethany Shivers  
Ro DiBrezzo

FROM: Ro Windwalker  
IRB Coordinator

RE: New Protocol Approval

IRB Protocol #: 10-11-268

Protocol Title: *Effects of Head Position and Head-Supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals*

Review Type: ☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB

Approved Project Period: Start Date: 01/24/2011 Expiration Date: 12/07/2011

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Compliance website (<http://www.uark.edu/admin/rsspinfo/compliance/index.html>). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

If you wish to make *any* modifications in the approved protocol, you must seek approval *prior* to implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 120 Ozark Hall, 5-2208, or [irb@uark.edu](mailto:irb@uark.edu).



# UNIVERSITY OF ARKANSAS

Office of Research Compliance  
Institutional Review Board

August 12, 2011

## MEMORANDUM

TO: Bethany Shivers  
Ro DiBrezzo

FROM: Ro Windwalker  
IRB Coordinator

RE: PROJECT MODIFICATION

IRB Protocol #: 10-11-268

Protocol Title: *Effects of Head Position and Head-Supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals*

Review Type: ☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB

Approved Project Period: Start Date: 08/11/2011 Expiration Date: 12/07/2011

Your request to modify the referenced protocol has been approved by the IRB. **This protocol is currently approved for 18 total participants.** If you wish to make any further modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

Please note that this approval does not extend the Approved Project Period. Should you wish to extend your project beyond the current expiration date, you must submit a request for continuation using the UAF IRB form "Continuing Review for IRB Approved Projects." The request should be sent to the IRB Coordinator, 210 Administration.

For protocols requiring FULL IRB review, please submit your request at least one month prior to the current expiration date. (High-risk protocols may require even more time for approval.) For protocols requiring an EXPEDITED or EXEMPT review, submit your request at least two weeks prior to the current expiration date. Failure to obtain approval for a continuation *on or prior to* the currently approved expiration date will result in termination of the protocol and you will be required to submit a new protocol to the IRB before continuing the project. Data collected past the protocol expiration date may need to be eliminated from the dataset should you wish to publish. Only data collected under a currently approved protocol can be certified by the IRB for any purpose.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or [irb@uark.edu](mailto:irb@uark.edu).

210 Administration Building • 1 University of Arkansas • Fayetteville, AR 72701  
Voice (479) 575-2208 • Fax (479) 575-3846 • Email [irb@uark.edu](mailto:irb@uark.edu)

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# UNIVERSITY OF ARKANSAS

Office of Research Compliance  
Institutional Review Board

December 16, 2011

## MEMORANDUM

TO: Bethany Shivers  
Ro DiBrezzo

FROM: Ro Windwalker  
IRB Coordinator

RE: PROJECT CONTINUATION / MODIFICATION

IRB Protocol #: 10-11-268

Protocol Title: *Effects of Head Position and Head-Supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals*

Review Type: ☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB

Previous Approval Period: Start Date: 01/24/2011 Expiration Date: 12/07/2011

New Expiration Date: 12/07/2012

Your request to extend and modify the referenced protocol has been approved by the IRB. If at the end of this period you wish to continue the project, you must submit a request using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. Failure to obtain approval for a continuation on or prior to this new expiration date will result in termination of the protocol and you will be required to submit a new protocol to the IRB before continuing the project. Data collected past the protocol expiration date may need to be eliminated from the dataset should you wish to publish. Only data collected under a currently approved protocol can be certified by the IRB for any purpose.

**This protocol has been approved for 18 participants.** If you wish to make any modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or [irb@uark.edu](mailto:irb@uark.edu).

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# UNIVERSITY OF ARKANSAS

Office of Research Compliance  
Institutional Review Board

January 31, 2012

## MEMORANDUM

TO: Bethany Shivers  
Ro DiBrezzo

FROM: Ro Windwalker  
IRB Coordinator

RE: PROJECT MODIFICATION

IRB Protocol #: 10-11-268

Protocol Title: *Effects of Head Position and Head-Supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals*

Review Type: ☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB

Approved Project Period: Start Date: 01/31/2012 Expiration Date: 12/07/2012

Your request to modify the referenced protocol has been approved by the IRB. **This protocol is currently approved for 54 total participants.** If you wish to make any further modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

Please note that this approval does not extend the Approved Project Period. Should you wish to extend your project beyond the current expiration date, you must submit a request for continuation using the UAF IRB form "Continuing Review for IRB Approved Projects." The request should be sent to the IRB Coordinator, 210 Administration.

For protocols requiring FULL IRB review, please submit your request at least one month prior to the current expiration date. (High-risk protocols may require even more time for approval.) For protocols requiring an EXPEDITED or EXEMPT review, submit your request at least two weeks prior to the current expiration date. Failure to obtain approval for a continuation *on or prior to* the currently approved expiration date will result in termination of the protocol and you will be required to submit a new protocol to the IRB before continuing the project. Data collected past the protocol expiration date may need to be eliminated from the dataset should you wish to publish. Only data collected under a currently approved protocol can be certified by the IRB for any purpose.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or [irb@uark.edu](mailto:irb@uark.edu).

210 Administration Building • 1 University of Arkansas • Fayetteville, AR 72701  
Voice (479) 575-2208 • Fax (479) 575-3846 • Email [irb@uark.edu](mailto:irb@uark.edu)

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# UNIVERSITY OF ARKANSAS

Office of Research Compliance  
Institutional Review Board

May 14, 2012

## MEMORANDUM

TO: Bethany Shivers  
Ro DiBrezzo

FROM: Ro Windwalker  
IRB Coordinator

RE: PROJECT MODIFICATION

IRB Protocol #: 10-11-268

Protocol Title: *Effects of Head Position and Head-Supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals*

Review Type: ☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB

Approved Project Period: Start Date: 05/14/2012 Expiration Date: 12/07/2012

Your request to modify the referenced protocol has been approved by the IRB. **This protocol is currently approved for 54 total participants.** If you wish to make any further modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

Please note that this approval does not extend the Approved Project Period. Should you wish to extend your project beyond the current expiration date, you must submit a request for continuation using the UAF IRB form "Continuing Review for IRB Approved Projects." The request should be sent to the IRB Coordinator, 210 Administration.

For protocols requiring FULL IRB review, please submit your request at least one month prior to the current expiration date. (High-risk protocols may require even more time for approval.) For protocols requiring an EXPEDITED or EXEMPT review, submit your request at least two weeks prior to the current expiration date. Failure to obtain approval for a continuation *on or prior to* the currently approved expiration date will result in termination of the protocol and you will be required to submit a new protocol to the IRB before continuing the project. Data collected past the protocol expiration date may need to be eliminated from the dataset should you wish to publish. Only data collected under a currently approved protocol can be certified by the IRB for any purpose.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or [irb@uark.edu](mailto:irb@uark.edu).

210 Administration Building • 1 University of Arkansas • Fayetteville, AR 72701  
Voice (479) 575-2208 • Fax (479) 575-3846 • Email [irb@uark.edu](mailto:irb@uark.edu)

*The University of Arkansas is an equal opportunity/affirmative action institution.*

**APPENDIX F**  
**US Army MRMCI IRB Approval and Modification Memoranda**



DEPARTMENT OF THE ARMY  
US ARMY MEDICAL RESEARCH AND MATERIEL COMMAND  
504 SCOTT STREET  
FORT DETRICK, MD 21702-5012

MCMR-RPI

28 June 2011

#### MEMORANDUM FOR THE RECORD

SUBJECT: Initial Approval for the Protocol, "Effects of Head Position and Head-Supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals," Submitted by Valeta C. Chancey, Ph.D., U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, USAARL Study Number 2010-048, Log Number M-10085

1. The subject research protocol was reviewed by the Headquarters, U.S. Army Medical Research and Materiel Command Institutional Review Board (HQ USAMRMC IRB) on 9 March 2011 and was approved as a no greater than minimal risk study with stipulations for minor changes. The final version of requested revisions to the protocol and supporting documents were received on 27 June 2011.
2. The research protocol (version 27 June 2011), consent form (version 21 June 2011), and recruitment flyer (21 June 2011) have been reviewed and found to comply with the recommendations of the HQ USAMRMC IRB and with applicable Federal, DOD, U.S. Army, and USAMRMC human subjects protection requirements.
3. There are no outstanding human subject protection issues to be resolved. The protocol is approved for a one-year period, 9 March 2011 to 8 March 2012 pending approval of the USAARL Commander.
4. The protocol is approved to recruit, screen, and enroll up to 36 subjects to obtain 18 evaluable subjects.
5. In accordance with 32 CFR 219.109(e), the protocol must be reviewed for continuation by the HQ USAMRMC IRB. A continuing review report with a copy of the current research protocol and consent form must be submitted at in time for the convened IRB to review and approval on or before the expiration date.
6. Any modifications (including, but not limited to, changes in the principal investigator, inclusion/exclusion criteria, number of subjects to be enrolled, or procedures) must be submitted as a written amendment for the HQ USAMRMC IRB's review and approval prior to implementation.
7. Any deviation to the protocol that may have an effect on the safety or rights of the subject or the integrity of the study must be reported to the HQ USAMRMC IRB as soon as the deviation is identified.



MCMR-RPI

SUBJECT: Initial Approval for the Protocol, "Effects of Head Position and Head-Supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals," Submitted by Valeta C. Chancey, Ph.D., U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, USAARL Study Number 2010-048, Log Number M-10085

8. Unanticipated problems involving risk to subjects or others, all serious adverse events, and all subject deaths must be promptly reported by telephone (301-619-6240), by e-mail ([irboffice@amedd.army.mil](mailto:irboffice@amedd.army.mil)), or by facsimile (301-619-4165) to the HQ USAMRMC IRB. A complete written report should follow the initial notification.

9. A final report must be submitted to the HQ USAMRMC IRB.

10. The point of contact for this protocol is Ms. Marianne M. Elliott, M.S., C.I.P., Senior Human Subject Protection Scientist at 301-619-3043 or [marianne.m.ctr@us.army.mil](mailto:marianne.m.ctr@us.army.mil).

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PITTMAN.PHILLIP.RICHARD.1114926082  
DN: c=US, o=U.S. Government, ou=DoD,  
ou=PM, ou=USA,  
cn=PITTMAN.PHILLIP.RICHARD.1114926082  
Date: 2011.06.28 16:18:19 -0400

PHILLIP R. PITTMAN, MD, MPH  
Chair  
Headquarters, U.S. Army Medical Research  
and Materiel Command  
Institutional Review Board



DEPARTMENT OF THE ARMY  
US ARMY MEDICAL RESEARCH AND MATERIEL COMMAND  
504 SCOTT STREET  
FORT DETRICK, MD 21702-5012

MCMR-RPI

27 July 2011

MEMORANDUM FOR THE RECORD

SUBJECT: Amendment #1 to the Protocol, "Effects of Head Position and Head-supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals" Submitted by Valeta Carol Chancey, Ph.D, U.S. Army Aeromedical Research Laboratory (USAARL), USAARL Protocol Number 2010-048, IRB Log Number M-10085

1. The Headquarters, U.S. Army Medical Research and Materiel Command Institutional Review Board (HQ USAMRMC IRB) reviewed this research protocol on 9 March 2011 and gave final approval on 28 June 2011.
2. The amendment includes:
  - a. Addition of research personnel (Tyler Rooks); and
  - b. Minor changes to equipment and procedures.
3. This amendment does not pose any new or additional risks to participants beyond those identified in the previously approved protocol. The amendment was reviewed as a minor change to previously approved research using an expedited review procedure allowed by 32 CFR 219.110(b)(2).
4. The amendment includes revised documents: research protocol (version 25 July 2011). These documents have been reviewed and found to comply with applicable Federal, DOD, U.S. Army, and USAMRMC human subject protection requirements. Amendment #1 is approved.
5. The Principal Investigator is responsible for fulfilling the following reporting requirements to the HQ USAMRMC IRB outlined in the original approval memorandum of 28 June 2011. The approval for this research expires on 8 March 2012.
6. The point of contact for this study is Ms. Marianne Elliott, MS, CIP, Senior Human Subject Protection Scientist, at 301-619-3043 or Marianne.m.Elliott.ctr@us.army.mil.

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PHILLIP R. PITTMAN, MD, MPH  
Chair  
Headquarters, U.S. Army Medical Research  
and Materiel Command  
Institutional Review Board



REPLY TO  
ATTENTION OF

DEPARTMENT OF THE ARMY  
US ARMY MEDICAL RESEARCH AND MATERIEL COMMAND  
504 SCOTT STREET  
FORT DETRICK, MD 21702-5012

MCMR-RPI

21 December 2011

# MEMORANDUM FOR THE RECORD

SUBJECT: Amendment #2 to the Protocol, "Effects of Head Position and Head-supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals," Valeta Carol Chancey, Ph.D, U.S. Army Aeromedical Research Laboratory (USAARL), Protocol Number 2010-048, IRB Log Number M-10085

1. The Headquarters, U.S. Army Medical Research and Materiel Command Institutional Review Board (HQ USAMRMC IRB) reviewed this research protocol on 9 March 2011 and gave final approval on 28 June 2011. The IRB Vice Chair approved amendment #2 on 21 December 2011.
2. This memorandum corrects an administrative error in the IRB-approved recruitment flyer (efile name version 21 December 2011). Please use this version for recruitment purposes.
3. The point of contact for this study is Ms. Marianne Elliott, MS, CIP, Senior Human Subject Protection Scientist, at 301-619-3043 or Marianne.m.Elliott.ctr@us.army.mil.

*Marianne Elliott*

MARIANNE M. ELLIOTT, M.S., C.I.P.  
Senior Human Subject Protection Scientist  
Acting, Director, Institutional Review Board  
Office  
Office of Research Protections



DEPARTMENT OF THE ARMY  
US ARMY MEDICAL RESEARCH AND MATERIEL COMMAND  
504 SCOTT STREET  
FORT DETRICK, MD 21702-5012

MCMR-RPI

11 January 2012

#### MEMORANDUM FOR THE RECORD

SUBJECT: Amendment #3 to the Protocol, "Effects of Head Position and Head-supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals," Valeta Carol Chancey, Ph.D, U.S. Army Aeromedical Research Laboratory (USAARL), USAARL Study Number 2010-048, IRB Log Number M-10085

1. The Headquarters, U.S. Army Medical Research and Materiel Command Institutional Review Board (HQ USAMRMC IRB) reviewed this research protocol on 9 March 2011 and gave final approval on 28 June 2011.
2. An amendment request was received 6 January 2012. The amendment includes:
  - a. availability plan for the study physician/associate investigator and on-site resources,
  - b. increase in enrollment of up to 54 subjects to obtain 18 evaluable subjects,
  - c. updated and expanded medical history questionnaire,
  - d. revised recruitment flyer, and
  - e. revised consent form indicating that students may be offered extra credit for participation by University professors and instructors.
3. This amendment does not pose any new or additional risks to participants beyond those identified in the previously approved protocol. The amendment was reviewed as a minor change to previously approved research using an expedited review procedure allowed by 32 CFR 219.110(b)(2).
4. The amendment includes revised documents: research protocol (version 10 January 2012, Study Physician/AI Statement and Availability Plan, Medical History Questionnaire with Standards (version 10 January 2012), recruitment flyer (version 10 January 2012) and consent form (version 10 January 2012). These documents have been reviewed and found to comply with applicable Federal, DOD, U.S. Army, and USAMRMC human subjects protection requirements. Amendment #3 is approved.





DEPARTMENT OF THE ARMY  
 US ARMY MEDICAL RESEARCH AND MATERIEL COMMAND  
 604 SCOTT STREET  
 FORT DETRICK, MD 21702-6012

MCMR-RPI

26 March 2012

#### MEMORANDUM FOR THE RECORD

SUBJECT: Continuing Review and Amendment #4 Approval, and Reportable Events Reports Acceptance for the Protocol, "Effects of Head Position and Head-Supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals," Submitted by Valeta C. Chancey, Ph.D., U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, USAARL Study Number 2010-048, Log Number M-10085

1. The subject no greater than minimal risk protocol was initially approved by the Headquarters, U.S. Army Medical Research and Materiel Command's Institutional Review Board (HQ USAMRMC IRB) on 9 March 2011 with stipulations for minor changes. Final approval was granted on 28 June 2011.
2. The HQ USAMRMC IRB reviewed the protocol for continuation on 29 February 2012 and re-approved it for a period of one year. Three reportable events reports were reviewed and accepted.
3. The HQ USAMRMC IRB also reviewed and approved an amendment request (allowing for minor adjustment to the head positions, removal of visual cues, adjustment to recruiting process, and minor editing) with stipulations for minor changes. Revised documents received 21 March 2012 have been reviewed and found to comply with the recommendations of the HQ USAMRMC IRB and with applicable Federal, DOD, U.S. Army, and USAMRMC human subject protection requirements.
4. There are no outstanding human research protections issues to be resolved. The research protocol (version 9 March 2012), consent form (version 9 March 2012) and supporting documents are approved for a period of one year expiring on 8 March 2013. Note that the continuing review date is set based on the previous expiration date of the protocol, 8 March 2012. Amendment #4 is approved.
5. The Principal Investigator is responsible for fulfilling the following reporting requirements to the HQ USAMRMC IRB:
  - a. Any modifications must be submitted as a written amendment for HQ USAMRMC IRB review and approval prior to implementation.
  - b. All unanticipated problems involving risks to subjects or others and serious adverse events must be reported promptly to the HQ USAMRMC IRB by telephone at

MCMR-RPI

SUBJECT: Continuing Review and Amendment #4 Approval for the Protocol, "Effects of Head Position and Head-Supported Mass on Nerve Function Measured in the Flexor Carpi Radialis Muscle in Healthy Individuals," Submitted by Valeta C. Chancey, Ph.D., U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, USAARL Study Number 2010-048, Log Number M-10085

301-619-6240, by facsimile to 301-619-4165 or by email to IRBOFFICE@amedd.army.mil.

c. Any deviation to the research protocol that may affect the safety or rights of the subject and/or integrity of the research data must be reported promptly to the HQ USAMRMC IRB.

d. The research protocol must be approved for continuation by the HQ USAMRMC IRB no later than 8 March 2013.

e. The final research report and any supporting documents must be submitted to the HQ USAMRMC IRB whenever the research is finished or terminated and no later than the continuing review report deadline.

6. The IRB Office point of contact for this research is Marianne Elliott, MS, CIP, Senior Human Subjects Protection Scientist, at 301-619-3043 or Marianne.m.elliott.ctr@us.army.mil.

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PHILLIP R. PITTMAN, MD, MPH  
Chair  
Headquarters, U.S. Army Medical Research  
and Materiel Command  
Institutional Review Board

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DN: cn=P.RICHARD.111, o=U.S. Army, ou=USAMRMC, email=P.RICHARD.111@us.army.mil, c=US  
Date: 2013.03.28 16:25:04 -0500

